Sky and TELESCOPE

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Sky and TELESCOPE

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LETTERS

Sir:

After publication of my article on astronautical periodicals in the February issue of *Sky and Telescope*, page 169, I was informed of the activities of the Sociedade Interplanetaria do Rio de Janeiro in Brazil. This society, which was organized in November, 1956, publishes a mimeographed bulletin in Portuguese.

The organization has about 120 members, and plans to become a member of the International Astronautical Federation.

FREDERICK I. ORDWAY, III
General Astronautics Corporation

Sir:

In reference to Otto Struve's remarks on the rarity of supernovae (January and February issues, pages 116 and 174 respectively), the following extract from a letter written on December 11, 1572, may be of interest. It appears in an old volume (1846) titled *Original Letters, Illustrative of English History*, collected by Sir Henry Ellis (3rd Series, Vol. IV), which I happened to read recently in connection with some research on the early history of Puritanism.

The writer of the letter was Sir Thomas Smith, a leading Protestant reformer and Elizabethan statesman who had just returned from a mission in France; he was writing a colleague still in France. Smith, of course, is speaking of Tycho's supernova.

"I am sure you have heard of, and I thincke you have seene the new faire Starre, or Comett, but without beard or taile, which hath appeared here this three weekes, over the backside of the Chaire of Casseopea, and on the edge of Lactea Via; bignes is betwixt the bignes of Jupiter and Venus, and keepes, to my appearance, who have noe Instruments to observe it, and because of this cold weather also dare not, the precise order of fixed starres. Such an one never have I observed nor read of. I pray you lett me knowe what your wise men of Paris doe judge upon it."

WARREN H. CARROLL
Department of History
Indiana University

COLOR ON THE MOON

V. Axel Firsoff, *British Astronomical Association*

LUNAR COLORINGS are generally faint. In fact, at first glance the moon looks colorless. At night, the moon makes a dazzling telescopic sight even with a moderate aperture and magnification, for its brilliantly sunlit landscape is suddenly presented to the observer's dark-adapted eye. If we add to this the habit of looking at black-and-white lunar photographs and drawings, it is no wonder we see the moon's surface in monochrome.

Personally, I can hardly make out any lunar color until I ask myself how I would paint a particular feature. Then the color appears and stays. Withdrawing the eye from the eyepiece is also helpful, to restrict the field and isolate the feature under observation from its background.

One of the most definitely colored areas is a diamond-shaped stretch northeast of Aristarchus. This is easily made out as mustard yellow when the nearly full moon is high in the sky. Closer to quarter phase, the greenish-khaki tone of the southwestern foothills of the Apennines, where these mountains touch the Haemus range, is almost equally distinct.

Colors seen at phases much less than full are usually stronger and often different from those at full. The reduction in glare may have something to do with this, but the angles of incidence and reflection are certainly important factors. For visual color study, the moon should be high and the air clear. A low moon appears golden, because our atmosphere then scatters more of the light of short wave lengths. In fact, in thinking of lunar colors, we must never forget the earth's atmosphere.

Thus, in comparing lunar or planetary colors with those of terrestrial objects, we should not think in terms of our immediate surroundings but of horizon views, preferably telescopic, seven to 10 miles distant. Mountains provide the most suitable standard of comparison with the moon. I have observed Scottish hills through the same telescope I was using for lunar work, and found that generally the variety of hue was not much greater than on the moon, although grass, heather, peat, scree, bare rock, water, and snow were undoubtedly present. If we could see the moon without the interference of our atmosphere, it would appear far more colorful than it does now.

Only predominant hues reveal themselves to a distant eye, especially if a monochromatic filter is used. Such a filter transmits only a narrow band of wave lengths. For example, if red predominates in an observed feature, it will look bright through a red filter and dark through a green or blue one. A yellowish surface may be comparatively bright with either a green or a red filter, but a blue or violet filter may show it coal black. Monochromatic filters can also reveal slight differences of hue and allow distinction to be made between seemingly identical whites, grays, or blacks. The white of snow, for instance, is not quite the same as that of quartz or magnesia.

In the past, some lunar observers have used filters that were not fully monochromatic, which adversely affected their results. Nowadays, however, excellent monochromatic filters are available in the Wratten series (Eastman), as well as in other makes (I am using mainly the Dufay tricolor set).

To trace faint gradations of intensity, comparisons between different color images must be made in quick succession. Therefore, I mounted a set of filters on a swivel behind the eyepiece, so that any of them could be brought to bear on the moon within a fraction of a second. My observations referred to below were obtained in this way, and cover several hundred determinations made at different lunations over a period of three years (1953-56).

My work, taken with the data of other observers, clearly shows that various colors exist on the moon, many of them subject to variation in the course of the lunar day, with possibly slower or nonperiodic changes as well. Individual findings generally agree, but considerable marginal differences persist.

Between 1910 and 1930, photographs of the moon were taken through color filters, first by R. W. Wood in the United States, and later by observers in Germany and Russia. Miethe and Seegert made ultraviolet and orange photographs, identifying numerous chromatic differences on the surface of the moon, most of which were subsequently confirmed in the 1926 survey made at Lick Observatory by W. H. Wright and Dorothy Applegate. Using the 36-inch Crossley reflector, the California astronomers secured some very fine negatives in ultraviolet, violet, green, orange, red, and extreme red. Six of these pictures are reproduced here from Wright's paper in *Publications* of the Astronomical Society of the Pacific, *41*, 125, 1929.

Comparison of the two sets of pictures is informative, even though markings of intermediate color, including light greens, would come out about equally intense in both sets. The photographic processes for the ultraviolet and extreme-red pictures were different, which may have introduced systematic effects. I believe that the far greater tolerance of the eye to contrast makes visual comparison superior, although it does not provide an objective record.

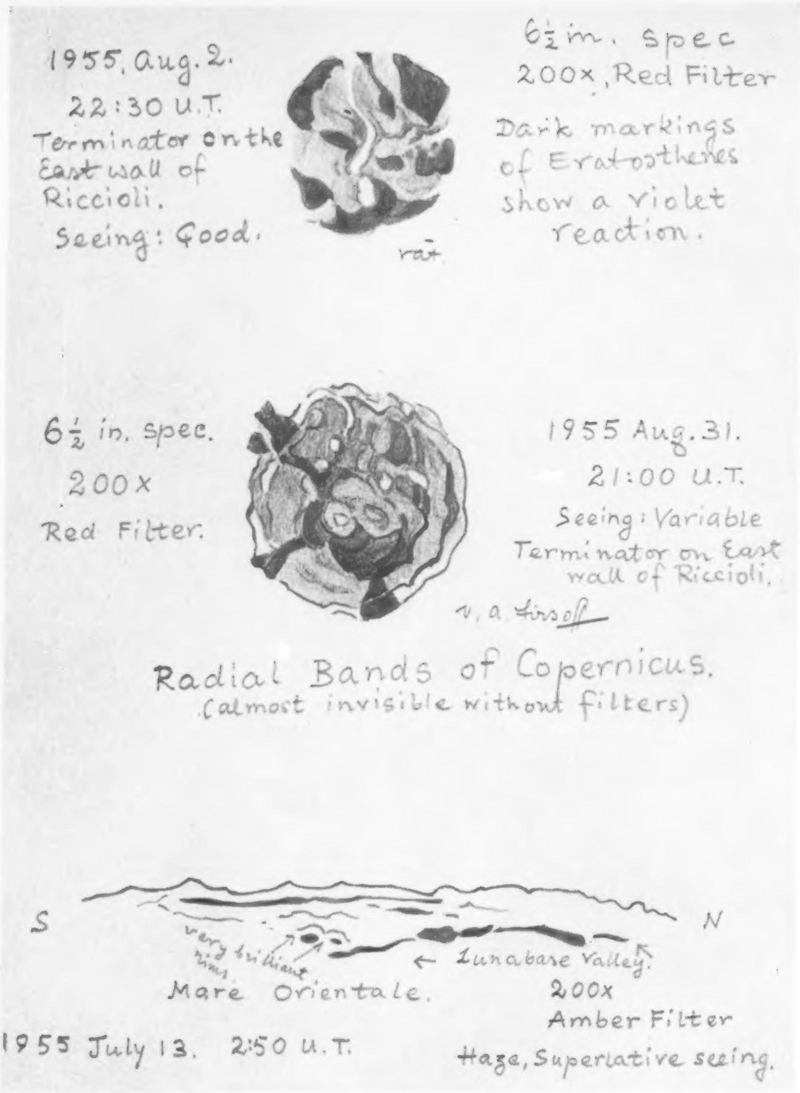
Wright noted the pallor of Mare Frigoris in extreme red. (I have found this area distinctly yellowish.) His photographs seem to show plainly what he does not mention, that the maria are generally more uniform in ultraviolet, while light of longer wave length seems to prevail among the highlands and some parts of the maria. Apart from the Aristarchus "diamond," the most conspicuous color areas are dark in extreme red and so presumably are intrinsically green or blue: the northeastern portion of Mare Imbrium, just south of Sinus Iridum, and in Mare Tranquillitatis and the edges of the plains adjoining it. There is a good deal of yellow and red in Oceanus Procellarum, and in parts of Mare Imbrium and Mare Serenitatis.

In recent years, an American amateur, D. P. Avigliano, carried out a systematic color survey of the moon, photographically as well as visually, with and without filters. Since black, gray, and white, which he lists among the colors observed by him, represent absence of coloration, while brown may be regarded as a shade of red or yellow, Avigliano has found on the moon only two colors, yellow and a little red. He states that his results are fully confirmed by his color photographs. On the other hand, Latimer J. Wilson is said to have obtained color photographs showing green in the maria.

Color photography, however, is not an impartial test. Any dominant color tends to smother all the rest. Also, overexposure gives a red bias, and underexposure exaggerates the shorter wave lengths. Thus, through differing choices of exposure times Wilson and Avigliano could easily get quite different results.

It is improbable that no colors other

FACING PICTURE: The moon in ultraviolet light (left column) and extreme red (right column), photographed with the Lick 36-inch Crossley reflector by W. H. Wright and Dorothy Applegate in September, 1926. The top two pictures are of the 10-day-old moon, the middle two at 15 days, and the last two at 20 days. The flattened edge in the second left-hand picture was caused by the filter boundary; the white hairline across Mare Serenitatis (second right-hand picture) and the white spot between Arzachel and Alphonsus in the lower left view are photographic defects. From "Publications" of the Astronomical Society of the Pacific. (See chart on page 331.)



Three drawings that show areas of special interest discussed in the text. They are Eratosthenes, Copernicus, and the region of Mare Orientalis.

than yellow and red exist on the moon. Many visual observers have described green, blue, and violet hues, and their presence is confirmed by Wright's photographs. Avigliano admits as much, and suggests differences in individual vision as a possible explanation. In many cases the color observed is olive or khaki, on the boundary between green and brown; purple is often described as brownish, and blue as very close to gray.

From 1934 to 1937, color observations were made in Germany by the Arbeitsgruppe für Mondbeobachtungen (Working Group for Lunar Observations), headed by F. Kaiser. Its members noted green in Mare Serenitatis, an occasional brown in Plato, as well as a cyclic variation in Ptolemaeus from gray or olive in the lunar morning to a yellowish tone toward evening.

Extensive observations by Walter H. Haas and his collaborators were reported in the *Journal* of the Royal Astronomical Society of Canada, *36*, 317, 1942. They described striking but very transient low-sun colors, chiefly on dark crater floors near the terminator. The hues were usually greens, sometime browns, and perhaps occasionally purples (or blues). High-sun colors, they found, were quite inconspicuous but very stable, being blue or purple in the dark areas, with delicate brown shadings and sometimes both blue and brown. Greens more than two days from the terminator were very rare.

In his book, *Our Moon,* H. P. Wilkins speaks of the greenish tint in Mare Crisium, Mare Tranquillitatis, Mare Humorum, and within the rings of Grimaldi and Ptolemaeus. I have never seen any strong green in Mare Crisium or Mare Tranquillitatis, but without filters I have noticed an olive tone in the latter and in Mare Serenitatis, also a bottle green in the dark spots of Sinus Medii and Mare Vaporum, as recorded by Rudaux. My observing book on September 11, 1954, for a practically full moon, reads:

"Western maria, also Humorum and Vaporum, noticeably darker in all colours, but especially in dichromatic purple (suppresses green), which throws them into bold relief. This would indicate a greenish tinge. Oceanus Procellarum and Mare Frigoris very pale in green and yellow. A yellowish-green hue can be made out even without filters."

This observation is in excellent agreement with Wright's photographs. Indeed, this yellowish-green tone appears to me to be most widespread on the moon, varying from brimstone to khaki. In the light of a young moon, even when the crescent appears reddish from contrast with the blue twilight sky, filters make it evident that the green component is strong; it is not quite so strong in a waning crescent. This greenness is spread over the whole disk, being very prominent in the earthlit portion. Earthshine is usually described as bluish, but my tests always put it first in green.

Most of the bright crater rims, floors, and rays are brightest in green. Occasionally, *terminator heights* show a strong green reaction, but usually they are brightest in red. Avigliano also noticed this effect, which I have verified again and again – even a deep-red Wratten 70 filter clearly shows terminator detail invisible in blue and violet.

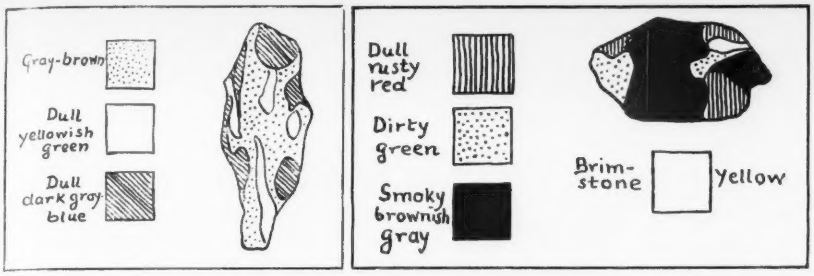
Let us view the moon successively through filters of different colors. In *red* the maria are dark, and the general relief is clear near the terminator. Differences in brilliance due to angle of illumination appear to be fairly smoothed out, while the limb brightening is less striking than without a filter.

With a *yellow* filter the maria are generally paler and the contrasts of light and shade are somewhat subdued, except for a few minor markings such as the spots in Eratosthenes, which appear very dark.

A *green* filter brings out all the bright features, especially Tycho's rays, but there is a perceptible fading along the terminator, and the brilliance of the limb is enhanced.

In *blue* light the terminator's features are dull, some of its highlights barely being made out, but the limb is much brighter than the rest of the disk. This brightness spreads out at the poles into "caps," to which attention was first called by W. H. Pickering, who was also using a blue filter. Several minor bright areas are seen scattered about the lunar disk, mainly associated with the rayed craters.

In *violet,* the whole picture is duller still, the terminator detail being barely visible unless the moon is very high in a clear sky. The limb brightening is narrower than in the blue but remains strong, while the caps and some of the blue-bright regions appear slightly hazy, as though seen through a luminous veil.



Drawings by the author show color distributions in Grimaldi (left) and Plato (right), seen with a $6\frac{1}{2}$-inch reflector at 200x, from 22:30 to 22:50 Universal time, August 6, 1955. The boundaries are only approximate.

Although changes in the blue and violet features are in part undoubtedly due to variations in our atmospheric transmission, such changes are not uniform over the disk. In particular, near the eastern limb, just west of Mare Orientalis, there is a conspicuous dark valley ("a flooded crater chain"), which is occasionally so faint in blue and violet as to be nearly invisible, while it remains perfectly evident in all the other colors. Another similar area covers the craters Walter and Regiomontanus and the neighborhood of the crater Hell.

The yellow diamond northeast of Aristarchus might be expected to appear very dark in violet and ultraviolet light. Wright's photographs show this. Yet I have often found it pale through a violet filter, and A. G. Smith, observing with an electronic image converter, also failed to see the expected ultraviolet darkening. In addition, he noted a bright ultraviolet area between Copernicus and the southern Apennines. He drew attention to the peculiar behavior of certain bright rays, sometimes strong in ultraviolet and sometimes in infrared.

Most of the changeable dark markings show some coloration, usually green, brown, or blue, often varying from one hue to another. The shaded areas of Eratosthenes, however, have a distinct violet tone, as was noticed by Pickering. This is startlingly demonstrated by monochromatic filters, when comparison is made with the nearby greenish markings of Sinus Medii and Mare Vaporum. Wright's photographs confirm this effect. Some markings, including the dark area in Riccioli, are of an indefinite blue-brown hue which Rudaux describes as smoked.

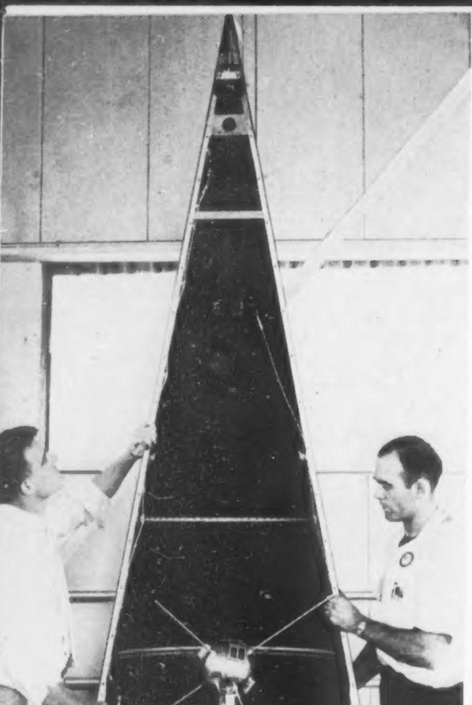
The general picture of color change is that the moon is greener at lunar sunrise than at sunset, and greener at the crescent phase or near the terminator. The weakening of the green component is paralleled by an intensification of the violet hue in the maria, certain craters, and localized areas. Some green, brown, blue, and violet hues persist in the maria and inside the rings. These probably represent the intrinsic coloring of the rocks or surface deposits.

It would be desirable to obtain progressive filter photographs to study these effects, but changes in exposure times can play havoc with the relative intensities of the colors.

KEY TO CHART OF MOON

1	Schickard	46	Goldschmidt
2	Schiller	47	Aristoteles
3	Scheiner	48	Eudoxus
4	Longomontanus	49	Cassini
5	Wilhelm I	50	Plato
6	Tycho	51	Aristillus
7	Maginus	52	Autolycus
8	Clavius	53	Archimedes
9	Newton	54	Timocharis
10	Cuvier	55	Eratosthenes
11	Stöfler	56	Copernicus
12	Maurolycus	57	Aristarchus
13	Pitiscus	58	Herodotus
14	Vlacq	59	Kepler
15	Janssen	60	Encke
16	Fabricius	61	Herschel
17	Zagut	62	Hevelius
18	Piccolomini	63	Riccioli
19	Furnerius	64	Grimaldi
20	Walter	65	Gassendi
21	Regiomontanus	66	Mersenius
22	Purbach	67	Pitatus
23	Arzachel	A	Leibnitz Mts.
24	Alphonsus	B	Mare Australe
25	Ptolemaeus	C	Altai Mts.
26	Hipparchus	D	Pyrenees Mts.
27	Albategnius	E	Mare Smythii
28	Abulfeda	F	Palus Somnii
29	Catharina	G	Mare Humboldt.
30	Cyrillus	H	Haemus Mts.
31	Theophilus	I	Caucasus Mts.
32	Fracastorius	J	Apennine Mts.
33	Santbech	K	Carpathian Mts.
34	Petavius	L	Straight Range
35	Phillips	M	Laplace Prom.
36	W. Humboldt	N	Sinus Iridum
37	Vendelinus	O	Heraclides Prom.
38	Langrenus	P	Alps Mts.
39	Macrobius	Q	Alpine Valley
40	Cleomedes	R	Riphaeus Mts.
41	Gauss	S	Straight Wall
42	Posidonius	T	Palus Putredinis
43	Hercules	U	Palus Nebularum
44	Atlas	V	Cordillera Mts.
45	Endymion	W	Doerfel Mts.

Chart of the moon drawn by Hugh S. Rice, American Museum-Hayden Planetarium. South is at the top, corresponding to the view in an astronomical or inverting telescope.



Vanguard I was protected by this nose cone of phenolic plastic. The two halves of the cone opened like a clam shell before the six-inch test satellite was propelled into its orbit from the third stage of the rocket.

Satellites and Space Research

Two New Artificial Satellites

THE MONTH of March saw important progress in the satellite-space exploration field. On March 17th the Naval Research Laboratory launched its six-inch test satellite, Vanguard I; on the 26th, the Army's Explorer III was placed in orbit; and the following day came the announcement of President Eisenhower's approval of Defense Department plans to send up lunar probe rockets.

The slim 72-foot three-stage Vanguard rocket incorporated some significant innovations. Its liquid-propelled first stage, 44 feet long, operated without stabilizing fins or vanes. The saving in weight, and therefore in power, was considerable, and a thrust of only 27,000 pounds was required, compared with the 80,000 pounds for the first stage of the Jupiter-C which launched Explorer I.

Vanguard's 31-foot second stage produced 7,500 pounds of thrust from a high-energy liquid fuel known as unsymmetrical dimethyl hydrazine. The third stage employed a solid-propellant rocket to raise the speed from 8,500 miles per hour to about 18,000. At this point, the burned-out third stage opened to release the satellite sphere. The mechanism for this can be seen in the accompanying photograph of the Vanguard nose cone.

Intended solely as a test, the new moonlet contains no instruments except two radio transmitters. One, powered by mercury batteries, was to send a 10-milliwatt signal for about two weeks. The other transmitter is solar powered, and its five-milliwatt signals at 108.03 megacycles should continue indefinitely.

The orbital period of the Vanguard satellite, 1958β, was 134.29 minutes on March 27th. Both the apogee and perigee heights, on that date 2,466 and 404 miles, respectively, were greater than for any previous artificial satellite, corresponding to an orbital eccentricity of 0.191. Because of the high perigee point, years will elapse before air drag will bring this object to its eventual destruction in the dense lower atmosphere.

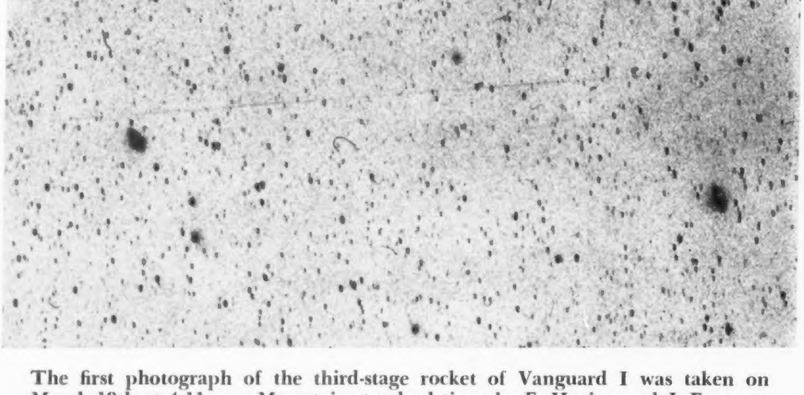
The Army missile launched from Cape Canaveral on March 26th is known as Explorer III, the name Explorer II having been used for the vehicle which failed to attain orbit 11 days earlier. As with the earlier Explorers, a three-stage Jupiter-C rocket was used, and the new satellite is also an 80-inch-long pencil-shaped object.

The satellite casing itself serves as the antenna for the two radio transmitters operating at the standard Minitrack frequencies of 108 and 108.03 megacycles. The cosmic-ray intensity measurements made from this satellite are not telemetered to earth continually, as with Explorer I. Instead, at a command from any of the 11 radio-tracking stations, a tape recorder reports in five seconds the data gathered within the previous 135 minutes.

This satellite, 1958γ, had been planned to move in an orbit with an apogee height of 1,270 miles and perigee at 218 miles above the earth's surface. But the orbit turned out to be more eccentric than intended, the actual distances being 1,677 and 119 miles on April 3rd. At that time the period was 114.56 minutes, and shortening by 0.165 minute per day. On April 3rd, after 91 revolutions around the earth, the apogee height was lessening by about nine miles per day. The probable lifetime of 1958γ will therefore be relatively short, an early estimate by the Naval Research Laboratory being four to six months.

The earth now has more known moons, natural and artificial, than the planet Uranus. With the growing number of temporary denizens of the upper atmosphere, the observing record set on March 20th at Albuquerque, New Mexico, may soon be surpassed. This was the sighting at one MOONWATCH session of three different satellites – Sputnik II, Vanguard I, and Explorer I.

At Albuquerque, the Kirtland Air Force Base MOONWATCHERS used 25 modified M-17 telescopes, as this is a special station equipped for apogee observations, together with a mobile radio receiver for advance warning that morning. Sputnik II was seen with the naked eye on its approach. But two objects were recorded telescopically, the second one passing two minutes 36 seconds later and $3\frac{1}{2}$ degrees lower in the sky. One of these was the Vanguard rocket carrier, the other its six-inch sphere. Less than 40 minutes later, the same team sighted Explorer I.



The first photograph of the third-stage rocket of Vanguard I was taken on March 19th at 4:11 a.m. Mountain standard time, by E. Horine and J. Emerson with a Harvard super-Schmidt camera at Organ Pass, New Mexico. The track of the satellite starts at the left above Gamma Bootis, moving eastward past Beta Bootis. Smithsonian Astrophysical Observatory photograph.

Exploration of the Moon

A LONG-RANGE program for scientific research in outer space has been presented to the National Academy of Sciences, providing a searching look into the space-exploration projects that may be undertaken as a continuation of the International Geophysical Year.

The proposals, prepared by the earth-satellite technical panel of the U. S. National Committee for the IGY, would extend already familiar artificial-satellite and sounding-rocket studies. In addition, there are suggestions for new biological experiments, ultraviolet solar photographs, and the like.

A major section of the recommendations deals with the moon. The simplest lunar experiments would involve striking the moon with a rocket. The impact velocity would be about 9,000 feet per second for a vehicle taking two or three days for the trip from the earth. Other observations would require circumlunar orbits, in some cases with instruments being lowered to the moon's surface. Much later, manned vehicles may be capable of landing on the moon.

The most useful experiments will be those that give information about the moon as a whole, rather than about some one place of impact. In particular, a measurement of the moon's mass is desired, for our present estimates may be in error by one part in 3,000 — enough to affect the calculations of moon-rocket trajectories. One method of mass determination would be to track a rocket approaching the moon, by means of a radar altimeter and a Doppler-drift measuring device inside the vehicle. Or such an instrument as a pendulum could be landed for the measurement of the acceleration of gravity at the moon's surface; but uncertainty in the precise distance of the measuring instrument from the center of the moon would probably limit the accuracy of this method.

A space vehicle could measure the moon's magnetic field, about which no definite information is yet available. At the distance of the moon, the terrestrial field is only 0.14 gamma (about 1/350,000 that at the earth's surface). The lunar field may be much stronger than this, perhaps due to internal circulations while our satellite was cooling; or it may be that the moon's magnetic field does not align itself with the extension of the earth's field. The establishment of either possibility would be important for tracing the history of the earth-moon system.

Another project concerns whatever atmosphere the moon may have, for it is too rarefied for astronomical observations to give any sure indication of its existence. Even heavy gases would slowly escape from the sunlit side of the moon. But perhaps gas trapped in the crust is steadily leaking out, so there would be a very tenuous but constantly replenished lunar atmosphere (see page 342).

Both the density and atomic composition of such an atmosphere might be determined with a lightweight mass spectrograph. If successful measurements could be made at the moon's surface, they would aid in understanding the constitution of the crust and its origin.

Seismic observations would prove very valuable. For example, listening for moonquakes would be one way to establish whether or not the moon has a molten core. Also, the impacts of large meteoritic masses striking anywhere on the moon might be detectable as waves in the crust.

The methods of seismic prospecting are available if an explosion could be caused on the lunar surface at a known time and distance from the recorder. The original shock wave, after traveling a short distance in the crust, would break up into groups of waves traveling at different speeds and along different paths, so the seismic recorder would need considerable time resolution — its data would be transmitted to the earth by a playback mechanism.

To produce the shock waves, an atomic explosion might be used, or possibly simply the impact of another part of the moon rocket carrying the seismometer. If an 800-pound object struck at 9,000 feet per second, the energy released would correspond to nearly its weight in TNT.

The broad program of space exploration, of which these lunar proposals are only a part, will probably first be attempted by unmanned vehicles. The technical panel comments:

"The attainment of manned space flight . . . cannot now be very clearly justified on purely rational grounds. It is possible, at least in principle, to design equipment which will do all the sensing needed to explore space and the planets. Mobile vehicles could be designed to land and crawl across the face of each of these distant worlds, measuring, touching, looking, listening, and reporting back to earth all the impressions gained. They could be remotely controlled, and so could act like hands, eyes, and ears for the operator on earth. Moreover, such robots could be abandoned without a qualm when they ran out of fuel or broke down."

However, the report continues:

"Though all of this could be done *in principle,* there may be a point at which the complexity of the machine to do the job becomes intolerable, and a man is found to be more efficient, more reliable, and above all more resourceful when unexpected obstacles arise. It is, in a sense, an article of faith that man will indeed be required to do the job of cosmic exploration personally — and, furthermore, that he will *want* to do the job himself, whether required to or not."

No timetable can be given for the achievement of the various stages in this American program for the exploration of space. But the first step was taken on March 27th, with the announcement that President Eisenhower had approved Department of Defense projects for the launching of small unmanned "lunar probe" rockets to the moon.

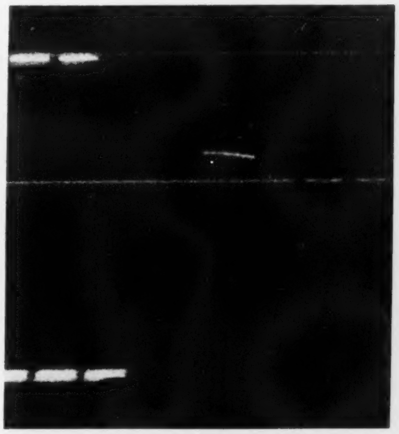
Authority to undertake one and possibly two lunar probes was given to the Army Ballistic Missile Agency at Huntsville, Alabama; modified Jupiter-C rockets will probably be used. In addition, the Air Force Ballistic Missile Division at Los Angeles, California, was assigned a program calling for three lunar probes. This project will probably employ a Thor-Vanguard system with a third stage yet to be developed. An initial outlay of eight million dollars has been made to start these two projects.

Photographic Tracking Stations

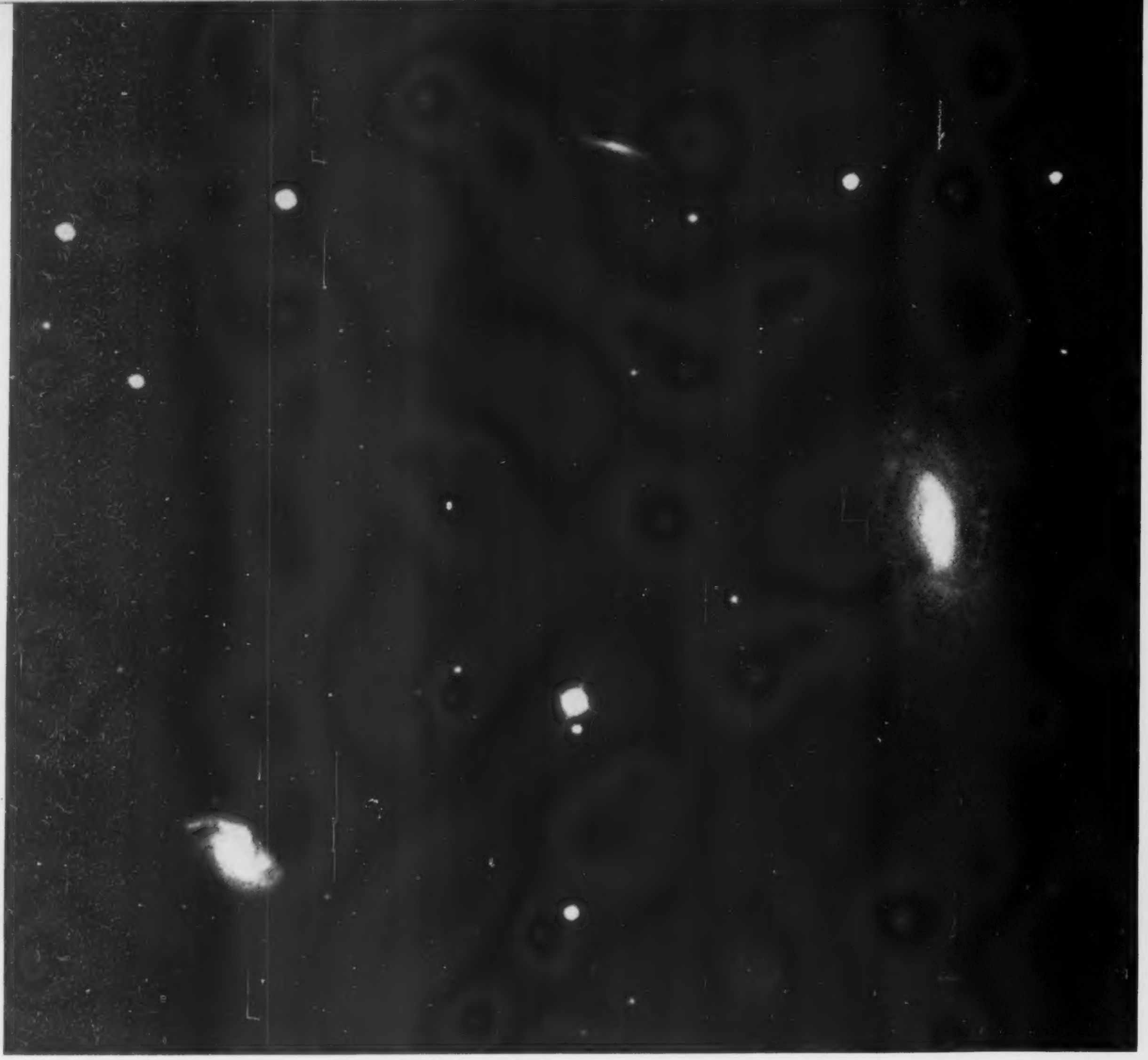
ALL 12 of the Smithsonian Astrophysical Observatory's satellite-tracking stations are expected to have Baker-Nunn cameras (*Sky and Telescope,* January, 1957, page 108) in operation by June 15th. Costing $70,000 each, these massive f/1 Schmidts are custom made for the difficult task of obtaining accurate positions of faint, fast-moving objects.

Six of the instruments have already been put into operation, in New Mexico, South Africa, Spain, Australia, Japan, and India. Three more were scheduled to be shipped in April to Peru, Iran, and Netherlands West Indies, and the final three in May to Florida, Argentina, and Hawaii.

The camera at Olifantsfontein, South Africa, under the supervision of Robert Cameron, an American astronomer, obtained the first photograph of 1958α on March 18th, at 7:50 p.m. local time. The satellite was some 800 miles high, about midway between perigee and apogee, when the fast sweep of the camera caught it to record the short trail reproduced here. The camera was pointed and driven on the basis of predictions of the satellite passage that were provided by W. S. Finsen, Union Observatory, Johannesburg.



Explorer I appears as the short track between the heavy trails of Epsilon Hydrae (top) and Rho Hydrae, as photographed in South Africa on March 18th.



Three different types of galaxies. At the left is NGC 440, the spiral wisp at the top is unnamed, and NGC 434 is at the right. This is a one-hour exposure without a filter on an Eastman 103a-O plate, made October 22, 1954, with the Radcliffe 74-inch reflector. North is at the top and the scale is 2.3 seconds of arc per millimeter.

Among Southern Galaxies—IV

LYING BEYOND the nearby group of galaxies at the south galactic pole, which includes NGC 253 and NGC 300 pictured in March and April, is the barred spiral NGC 613, shown on the facing page. It is a vast collection of stars, gas, and dust, its apparent dimensions being four by 5½ minutes of arc, distant from us by possibly 30 million light-years, according to G. de Vaucouleurs.

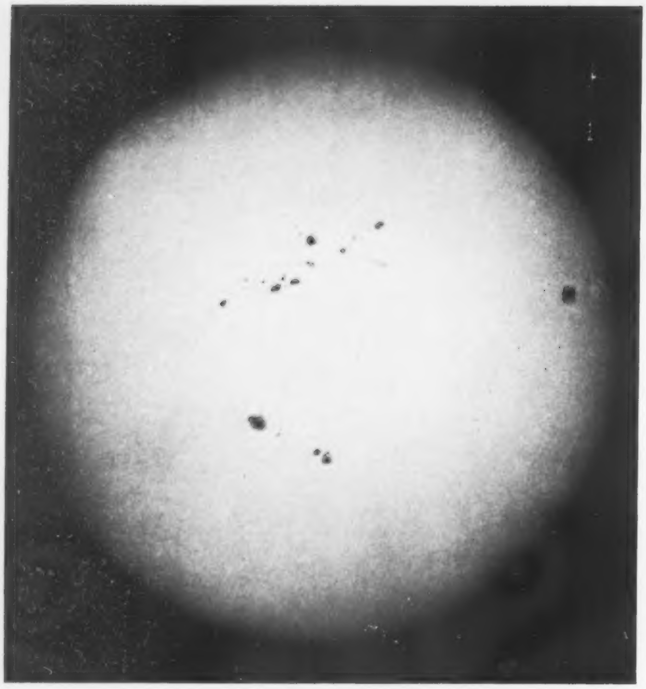
Its total brightness corresponds to magnitude 11 photographically, about equal to the conspicuous foreground star at the right in the picture. (The lines crossing this star's image were caused by diffraction of light past the secondary-mirror support of the 74-inch Radcliffe Observatory reflector.)

The galaxy's outer arms are partially resolved into stars of apparent magnitude 20 and fainter, together with some brighter knots of emission nebulosity. Note that dark lanes of obscuring material run parallel to the bar; they are stronger on the nearer side of the system.

NGC 613 is in Sculptor, at right ascension 1^h $32^m.0$, declination $-29°$ $40'$ (1950 co-ordinates). Its average spectral type is G5, with emission lines in the nuclear region, according to N. U. Mayall, Lick Observatory. The velocity of recession is some 1,500 kilometers per second. The de Vaucouleurs classification is SB(rs)bc, in the system explained on page 582 of October, 1957.

A short distance west of Achernar, the brightest star in Eridanus, lies the group of three galaxies pictured above. In the lower left is NGC 440, a peculiar spiral with high surface brightness, little detail, and thick twisted arms; it is about 40 seconds long. At the right is NGC 434, one by two minutes of arc in size, a normal Sa-type spiral with well-marked arms. The unnamed system at the top of the photograph is a spiral wisp with a bright linear core 20 seconds of arc in length.

FACING PICTURE: NGC 613 is a barred spiral with unusually complex arms. This one-hour exposure with the 74-inch Radcliffe Observatory reflector was made on November 16, 1952, using Eastman 103a-O emulsion without a color filter. This series of southern-galaxy pictures began in the February, 1958, issue. They are being published with the permission of R. H. Stoy, who is the director of the Royal Cape Observatory, Cape of Good Hope, South Africa.



The sun shines by continually converting its mass into energy. Photo by W. M. Kearons.

Einstein's Equation

$E = mc^2$

Otto Struve, *Leuschner Observatory*
University of California

ONE of the greatest scientific advances in the first half of this century is represented by the equation $E = mc^2$, Einstein's formulation of the equivalence of energy and mass. Physicists and astronomers use it often. Almost every high school or college student has heard the equation mentioned, and even newspaper accounts of scientific meetings frequently refer to it.

The derivation of Einstein's equation given in advanced textbooks uses the special theory of relativity and requires a certain amount of mathematics. In this article, however, we employ a hypothetical experiment that is easier to understand. We shall look into the necessary characteristics of electromagnetic radiation, such as the pressure of light, and use them to demonstrate Einstein's equation. Of fundamental importance is a basic idea of relativity theory, demonstrated by the famous Michelson-Morley experiment of 1881, that the speed of light in a vacuum is constant regardless of the motion of the source or the receiver.

Applications. The use of $E = mc^2$ can be illustrated by a few examples from astronomy. The sun radiates into space an enormous flood of energy, at a rate of 4×10^{33} ergs each second (about 5×10^{23} horsepower). This is the value for E in the equation. Since c, the velocity of light, is 3×10^{10} centimeters per second, c^2 is nearly 10^{21}. Solving the equation for m, we find that the sun is losing each second, in the form of radiation, a mass of $4 \times 10^{33}/10^{21} = 4 \times 10^{12}$ grams, or about four million tons per second.

In any discussion of the production of energy by thermonuclear reactions, whether in stars or in hydrogen bombs, this energy-mass relationship is of fundamental importance. The sun's light and heat come mainly from a reaction in which one gram of hydrogen is fused into 0.993 gram of helium. Seven-tenths of one per cent of the original mass is converted into energy. Hence, by Einstein's equation, the energy released as radiation from each gram of hydrogen is 0.007×10^{21} or 7×10^{18} ergs.

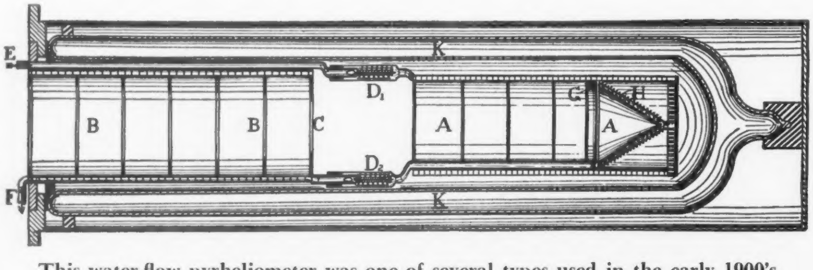
Finally, let us suppose that the entire mass of the sun, 2×10^{33} grams, could be converted into energy. The equation tells us that the energy released would be $2 \times 10^{33} \times 10^{21}$ or 2×10^{54} ergs. (No process by which the sun could be completely consumed in this way has yet been discovered.)

The solar constant. The rate at which solar energy reaches the earth's surface can be measured with an instrument called a pyrheliometer. In principle, it consists of a one-centimeter cube of water, one side of which may be exposed at right angles to the rays of the sun. At first a shutter in front of the cube cuts off all sunlight, and the temperature of the water is accurately determined. Then the shutter is opened, and the time required for the water temperature to rise one degree centigrade is measured. The amount of heat thus supplied to the water is, by definition, one calorie.

Experiments show that if the pyrheliometer were outside the earth's atmosphere, the shutter would have to be opened for about 30 seconds. We infer that the *solar constant* is about two calories per square centimeter per minute.

In astronomy it is customary to express energies in ergs rather than calories. One erg is the energy of motion possessed by a two-gram mass traveling one centimeter per second. (A flying mosquito has roughly one erg of such energy.) Since this kinetic energy is convertible into heat energy, the numerical conversion factor between ergs and calories is known as the mechanical equivalent of heat.

If, instead of admitting sunlight into the cube of water, we drop into it a two-gram pellet with a speed of one centimeter per second at impact, the temperature of the water would rise 1/42,000,000 of a degree. In other words, one calorie is the same as 42 million ergs. Thus, we can



This water-flow pyrheliometer was one of several types used in the early 1900's by Charles G. Abbot to measure the solar constant. Sunlight entered the orifice C from the left, passing through chamber A (diameter about 3½ centimeters) to the cone-shaped receiver H. There the energy heated water flowing in a spiral system of coils extending from the intake at E to the outlet at F. Platinum cells, D_1 and D_2, measured the rise of temperature of the water due to solar heating. A Dewar vacuum flask, K, enclosed the heat-receiving chamber. Reproduced from "Annals," Astrophysical Observatory of the Smithsonian Institution, 1913.

express the solar constant as 42 million ergs per square centimeter in 30 seconds, or 1.4×10^6 ergs per square centimeter per second.

Radiation pressure. During a single second, the square-centimeter face of the pyrheliometer cube receives light from a column above it having a cross section of one square centimeter and a length of 3×10^{10} centimeters. If the total amount of radiation energy reaching the cube in this interval is 1.4×10^6 ergs, then one cubic centimeter of the column contains $1.4 \times 10^6/3 \times 10^{10} = 4.7 \times 10^{-5}$ erg. This number represents the density of solar radiation at the distance of the earth.

Very delicate measurements, first made about 60 years ago by P. Lebedev in Moscow, show that this radiation exerts a pressure upon any object that intercepts it. If the obstacle is a perfect mirror, the sunlight pressure is $2 \times 4.7 \times 10^{-5} = 9.4 \times 10^{-5}$ dyne per square centimeter. (One dyne is the force required to accelerate one gram from rest to a speed of one centimeter per second by the end of one second.)

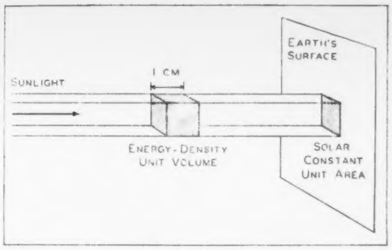
Both measurements and theory have shown that radiation pressure is proportional to radiation density. For example, if a telescope is used to concentrate the stream of solar radiation, let us say by a factor of 100, the density becomes 4.7×10^{-3} erg per cubic centimeter, and the pressure it exerts on a reflecting surface is 9.4×10^{-3} dyne per square centimeter.

When solar radiation falls on a black screen that absorbs all its energy, the pressure is only 4.7×10^{-5} dyne per square centimeter — that is, numerically the same as the radiation density. A. S. Eddington has remarked:

"We need not trouble to discriminate [between] the different cases of absorption, reflection, etc. The pressure on either side of the screen is equal to the energy-density of the radiation on that side, and the force on the screen corresponds to the difference of the pressures on its two sides. For example, in the case of the perfect reflector the pressure is equal to the total energy-density 2E on one side of the screen, viz. the energy-density E of the incident waves + the energy-density E of the reflected waves."

A hypothetical experiment. With the foregoing bird's-eye view of some radiation phenomena, we can proceed to discuss an imaginary experiment that will lead us to Einstein's equation, $E = mc^2$. We shall follow a line of reasoning due to the German physicist P. Lenard, a 1905 Nobel prize winner for his work on cathode rays, who based his thinking upon the earlier ideas by F. Hasenöhrl, of Vienna.

Suppose that on a sunny day we trap a small amount of sunlight within a cylinder whose inside surfaces are perfect mirrors. This is done by opening one end of the cylinder, T, for an instant until the



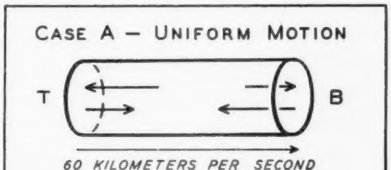
The relation between the solar constant and the unit of energy density.

rays reflected from the other end, B, begin to escape outward through the opening. At this moment the density of radiation in the cylinder is twice what it was outside, being $2 \times 4.7 \times 10^{-5}$ or approximately 10^{-4} erg per cubic centimeter.

The open end is closed tightly, and since its inside surface is also a perfect mirror the radiation trapped inside the container bounces back and forth between B and T. This radiation exerts a pressure upon both B and T that is numerically equal to the total radiation density, about 10^{-4} dyne per square centimeter. Within the container at any given instant there are equal numbers of rays traveling toward B and toward T, all with a velocity of 3×10^5 kilometers per second.

We shall now consider two distinct cases: **A.** The container is moving with a uniform velocity along the path of the rays. **B.** This motion is being accelerated, that is, the container is moving faster and faster. The first case will aid our understanding of the behavior of radiation inside the container; the second case corresponds to the actual derivation of Einstein's equation.

Case A. Assume that the cylinder is moving in the direction T-B with a uniform speed, say $v = 60$ kilometers per second. Therefore the mirror surface B seems

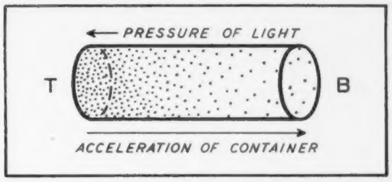


In this simple experiment, light is trapped in a moving cylinder; inside arrows indicate wave length.

to be receding with respect to the rays striking it and a Doppler shift will occur. If the rays initially have a wave length of 5000 angstrom units, they will appear to be lengthened at mirror B by $\lambda\, v/c$. This is $5000 \times 60/3 \times 10^5$, or one angstrom.

After reflection, the wave length is increased by the same amount, so instead of being 5000 angstroms it is now 5002. Hence, after reflection from B, any given amount of radiation occupies a larger volume, the increase being in the same proportion as the increase in wave length; consequently, the radiation density — the amount of energy per cubic centimeter — is smaller than it was initially, in the same ratio.

At the other end of the cylinder, the mirror surface T is moving forward, appearing to approach the light rays. They experience a Doppler shortening, also by two angstroms. The volume is now reduced and the energy density is restored to its original value. The total effect, after countless reflections from B and T, is for the *average* wave length to be exactly 5000 angstroms throughout the container. The radiation pressures upon B and T are still the same, equal to 10^{-4} dyne per square centimeter.



The end result of Case B is the concentration of energy toward T.

Case B. These conclusions are altered when we consider the second case, that of an accelerating container. The rays that first strike B experience a red shift. But since they then require a finite length of time to reach T, they experience a *larger* (violet) shift on reflection from T. Similarly, those rays that are first reflected from T undergo a small violet shift; by the time they get to B the container is moving faster, and there is a larger red shift on reflection from B. In both situations, the waves are more compressed near T than near B. Consequently, the radiation density is greater at T than at B, and the pressure against T exceeds the pressure against B.

We see that, because of radiation pressure inside the container, a force exists counteracting the acceleration imparted to the container from the outside. The radiation acts as though it has a certain mass whose inertia must be overcome when the cylinder is accelerated.

Energy-mass equivalence. The final step in our sequence of thought is to put the foregoing example into numerical terms that will show the equivalence of radiant energy and mass. Assume first that the container has a cross section of one square

centimeter and is 3×10^{10} centimeters long. Then its volume is 3×10^{10} cubic centimeters and, if the radiation density is 10^{-4} erg per cubic centimeter, the amount of radiation trapped within the cylinder is $3 \times 10^{10} \times 10^{-4} = 3 \times 10^{6}$ ergs.

Suppose the container is at rest when the rays first strike B. Because at any instant half the rays are moving to B and half toward T, their energy density at B is initially 0.5×10^{-4} erg per cubic centimeter, and the pressure exerted on B is 0.5×10^{-4} dyne per square centimeter. Since these rays travel at 3×10^{10} centimeters per second, they will reach T one second later. If the acceleration we are imparting from the outside is 6×10^{6} centimeters per second each second, the rays from B will reach T when its velocity is 6×10^{6} centimeters per second.

Repeat Case A's argument, where light of 5000 angstroms wave length experienced a violet shift of two angstroms. At T the radiation density is increased by one part in 2/5,000, and the pressure is likewise increased, becoming 2×10^{-8} dyne per square centimeter greater than at B.

The other half of the rays, those that reached T while the container was still at rest, are affected the same way. They leave T without change in radiation density or pressure, reaching B one second later, where they experience a red shift of two angstroms after reflection from B. Hence they simply maintain the pressure difference of 2×10^{-8} dyne between T and B.

Since the ends of the cylinders each have an area of one square centimeter, this pressure difference represents the force opposing the acceleration we are attempting to impart from the outside. (The force equals the pressure in dynes per square centimeter times the area upon which it presses.) Therefore, in order to maintain an acceleration of 6×10^{6} centimeters per second each second, we must apply a slightly greater force in the direction of motion than would be necessary if the cylinder contained no radiant energy at all.

By Newton's second law of motion, any force is equal to the product of the mass times its acceleration: $f = ma$. In our case, $2 \times 10^{-8} = m \times 6 \times 10^{6}$. Hence m, the mass of the radiation inside the cylinder, is 3.3×10^{-15} gram.

We have already seen, however, that the total amount of radiation within the container is 3×10^{6} ergs, and we need only to divide this value by the above mass value to find the proportionality factor in the energy-mass equation. Thus, $3 \times 10^{6}/3.3 \times 10^{-15}$ is about 9×10^{20}. But this is numerically equal to the square of the velocity of light! Therefore, we may write $E = mc^2$.

This is, of course, a demonstration for one particular instance, not a rigorous proof of the Einstein equation. The far-reaching physical significance of this great discovery by Einstein is suggested in the following words from Arthur Haas' *Introduction to Theoretical Physics:* "Lavoisier's law of the conservation of mass and the Mayer-Joule law of the conservation of energy are united by the theory of relativity into one single principle, for this theory regards as *constant* only the *sum* of the total energy contained in the universe and the total mass of the universe, multiplied by the square of the velocity of light."

QUESTIONS... FROM THE S+T MAILBAG

Q. **How much should I undercorrect my mirror to allow for the effects of night cooling?**

A. It should be fully corrected, for most amateur mirrors are not massive enough for much thermal lag during the slight cooling that usually takes place. Rapid cooling may last only a short while.

Q. What is the best power to use for comet sweeping?

A. Most comet seekers use about 20x to 50x; they strive for good light grasp and a field several degrees in diameter.

Q. Why do bright stars in photographs often show a pattern of spikes while galaxies in the same picture do not?

A. A star is essentially a point source and its light is diffracted as it passes the secondary-support arms which are found in the upper part of most reflectors. On the other hand, a galaxy is an extended object; each point is diffracted, but the patterns all blend together and do not show.

Q. What are the Clouds of Magellan?

A. The Large and Small Magellanic Clouds are our nearest neighbor galaxies. These hazy patches are situated in the sky near the south celestial pole, so are not visible to mid-northern observers.

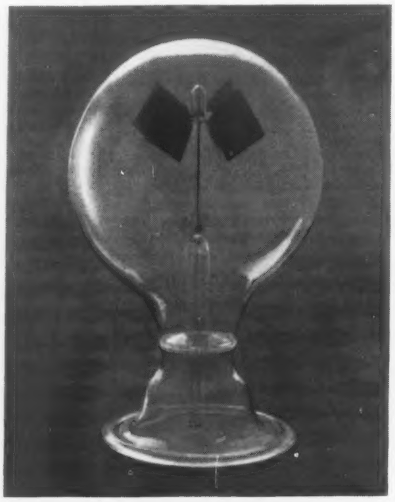
Q. Does a 10-power telescope make objects look 10 times larger or 10 times nearer?

A. They appear to have an angular extent 10 times greater, but the illusion is that the objects are nearer, as we are used to things looking larger as we approach them.

Q. Why do toy radiometers turn with the black sides of the vanes trailing, rather than leading as would be expected from radiation pressure?

A. Toy radiometers are only partially evacuated, so there is still an appreciable amount of air inside them. Radiation falling on the vanes is absorbed by the black sides, making them warmer than the white ones. The adjacent air is heated unequally, and the more energetic molecules on the black sides push them away.

W. E. S.



The vanes of this toy radiometer are coated white on one side and black on the other. Differential heating of the residual air causes the vanes to revolve with the white sides leading.

SEA-SURFACE GRAVIMETER

The first successful device for measuring the force of gravity on the ocean's surface has been put into use aboard the USS *Compass Island,* as part of the International Geophysical Year gravity program. The initial measurements with the new gravimeter, developed by Anton Graf of Munich, Germany, were made in the North Atlantic on November 22, 1957, by J. L. Worzel of Columbia University's Lamont Geological Observatory.

The relatively few prior determinations of gravity at sea had been made with pendulums in submarines submerged to depths where the ocean is quiet. Geophysicists have long desired an easier means for gravity surveys of the oceans and for intercomparing networks on land. The new gravimeter gathers the data about four times as fast as the submarine method, and the mathematical reductions are shortened considerably, which should make good gravity determinations more plentiful.

In the new device, a heavily damped horizontal aluminum boom is spring- and pivot-mounted on a gyro-stabilized platform. A large permanent magnet provides the damping by setting up eddy currents that brake the swinging motions of the boom. The position of the boom is determined by a differential photocell illuminated through a slit attached to the boom.

The output of the photocell, which changes whenever the slit moves, is amplified and traced on an Enograph recorder. Any variation in the value of gravity causes the boom to tilt, and five minutes are required for the complete registration of such a change.

Origin of the Aurora — II

JOSEPH W. CHAMBERLAIN

Yerkes Observatory
University of Chicago

Long slender rays and a bright arc low in the northeast are features of Mike Larson's photograph of the northern lights on March 11, 1958, at 8:17 p.m. Central standard time, from Ft. Dodge, Iowa. This fine display occurred about one solar revolution after the great auroral storm of February 10-11. The exposure was 10 seconds, at f/4.5 on Royal-X Pan film.

LAST MONTH the main observed facts about the northern lights were reviewed, especially the evidence that aurorae are produced, in part at least, by charged particles entering the atmosphere from extraterrestrial space. But we also noted that the various attempts to develop a quantitative theory of the aurora have met with many obstacles, because of insufficient data on the aurora itself and the mathematical difficulties of treating the problems involved.

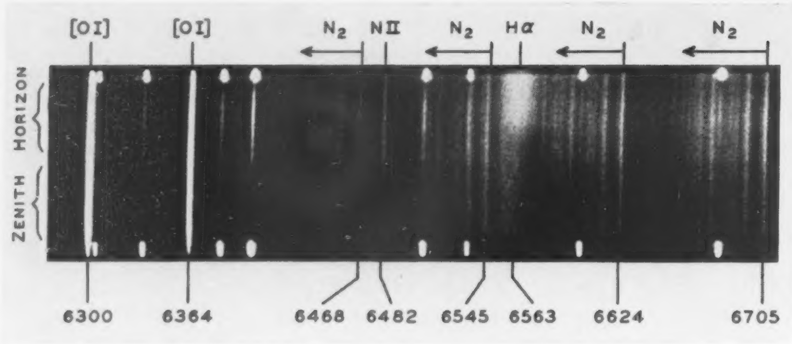
The case against current auroral theories. An auroral theory, developed with due regard for fundamental physical principles, can be quite useful, whether or not it ultimately proves correct, provided we keep in mind the proper role of theory in scientific method. A theory can guide the planning of experiments and observations, thus introducing some measure of order into what might otherwise become chaos. But inasmuch as an auroral theory is usually merely descriptive or phenomenological in nature, we must be cautious in accepting its postulates just because they predict some of the observed auroral characteristics.

Further, observational data are always subject to some error, and a phenomenon as difficult to observe and measure as the aurora is bound to lead to some incorrect findings. It is this state of affairs that has led one eminent theorist to assert, not entirely facetiously, "Never trust an observation until it is confirmed by theory." But it is quite different to adopt the attitude that observations are not to be trusted unless they conform to some previously existing theory. Yet we often adhere in our thinking to old ideas that seem to us logical and acceptable, even though on closer examination the reasons for their acceptance are not compelling and they do not really explain the facts.

In the 19th century the idea was prevalent that the aurora was produced by electric discharges. While laboratory experiments by de la Rive, Lemström, and Plante helped further this view, its origin can be traced to the middle of the 18th century and the analogies between lightning and the aurora drawn by Lomonosov, Canton, and Franklin.

Although the relation between auroral occurrences (at low latitudes, at least) and sunspot numbers was established in de Mairan's treatise of 1733, it was not until the 1870's that the proposal was made by Bequerel that the sun was the immediate source of aurora-producing particles. The 20th century has accordingly produced a variety of theories concerned with the propagation of solar ions into the earth's magnetic field.

Today we are gradually accumulating information about the passage of fast particles through air, and the excitation and radiation produced by particle collisions. While the results are not certain enough to provide the theorist with concrete information about the nature of auroral particles outside the earth, we can now apply fairly rigid tests to a

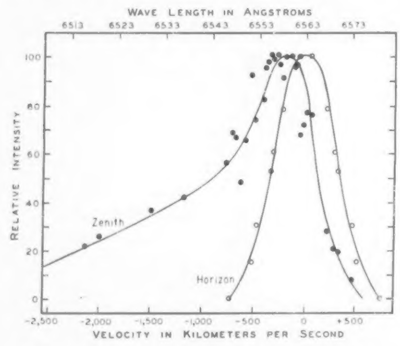


A spectrogram of the aurora of March 2, 1957, as photographed in the red with high dispersion, by the author and Vidya Pesch. Compare it with the right-hand part of the low-dispersion spectrum on page 270 of the April issue. To give a wave-length calibration, white dots were superimposed at the top and bottom from a laboratory neon source; the faint neon lines in the spectrum itself are contamination from advertising signs in a neighboring village. The two strongest auroral lines are from atomic oxygen, and many bands due to molecular nitrogen are recorded. In the horizon spectrum (upper part), the hydrogen-alpha line is symmetrical about its normal wave length, but near the zenith (lowest part) it is asymmetrical and displaced toward the violet. Yerkes Observatory photograph.

quantitative theory of the origin of these particles. These tests are not favorable to any existing theory.

For example, a solar-stream theory may suppose that aurorae are produced by protons bombarding the high atmosphere. This theory should predict at what distances from the magnetic poles and at what longitudes relative to the sun the hydrogen ions would be expected to enter the atmosphere. Further, the theory should explain the height of the aurora and the vertical distribution of luminosity. There are no theories of solar particles or particle streams that explain these items adequately; in fact, in no case does a theory even attempt to cope with all of these pertinent problems.

At the present time, we are just acquiring quantitative data on the auroral spectrum, the auroral luminosity versus height, and, from the program of the International Geophysical Year, geographical distribution and times of proton influx on the atmosphere. In addition, we are just now obtaining vital information about matter in the space immediately surrounding the earth. Hence we may be standing on the threshold of a new era in auroral theory, which may provide the long-sought answers. The vital ingredient, however, is likely to be bold and imaginative thinking as the facts are assimilated.



The structure of the hydrogen-alpha line in the spectrogram on this page is plainly shown by these curves of intensity against wave length. Each dot indicates a measurement by the author and Vidya Pesch. The bottom scale gives the corresponding line-of-sight velocities of the incoming protons, negative values indicating motion toward the observer.

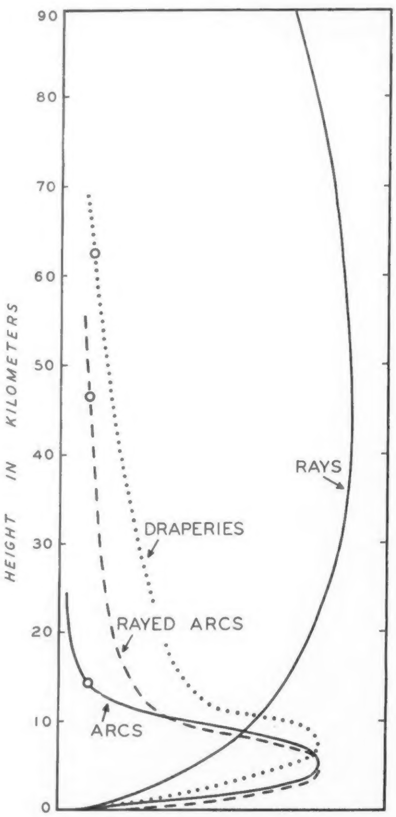
Nature of auroral protons. In the first installment, we noted the Doppler-shifted hydrogen lines in the spectra of some aurorae. A study of these spectral lines should give us information about the protons bombarding the atmosphere. It is not possible, unfortunately, to measure the shift in color of the hydrogen emission and deduce immediately the speed that the incoming particles had before they struck the atmosphere; rather, much detailed analysis is required.

To understand why the problem is complex, let us imagine a proton, that is, a hydrogen nucleus, moving into the atmosphere at several thousand miles per second, sufficiently fast to penetrate down to the 70-mile-height level. As the proton starts into the atmosphere it is gradually slowed by collisions with the oxygen and nitrogen that it encounters. These collisions also cause the oxygen and nitrogen to radiate.

But at this point there is almost no radiation characteristic of the hydrogen spectrum, because the proton cannot capture an electron to form a hydrogen atom until it is considerably slowed down. After enough encounters with atmospheric molecules, the proton will be traveling at only a few hundred or a thousand miles a second and it can steal an electron from one of the oxygen or nitrogen molecules as it passes by. As the capture takes place, the proton becomes a hydrogen atom and emits the characteristic red or blue light that we detect with a spectrograph. Thus, in order to deduce anything about the initial speed and direction of the incoming particles, we must investigate the atomic processes in detail.

Studies of this nature in recent years have indicated some rather startling features of the incoming protons. There are three significant things we measure about the hydrogen radiation. One is the profile — brightness versus wave length of the radiation — as we look along the earth's magnetic field. (The hydrogen lines are not strictly monochromatic but have a small width in wave length.) Another is the profile as we look perpendicular to the earth's magnetic field. Finally, there is the change in intensity of the radiation with height — the hydrogen luminosity curve.

The orientation of the earth's magnetic field is important, as we would expect charged particles, such as protons, to



These are typical luminosity curves for different auroral forms, after L. Vegard, showing the relative changes in brightness against height, which is measured from the lower border of each feature. The small circles indicate the upper limits of observation by photographic methods. Adapted from "The Aurorae," by L. Harang, Chapman and Hall, London, 1951.

move into the earth's atmosphere primarily in the direction of the magnetic field. The particles may, however, spiral about the magnetic lines of force.

For an observer who is far enough north to see the aurora frequently, these magnetic lines of force extend out of the earth in a direction just a few degrees south of his zenith. Therefore, to look right along the direction of the incoming particles we would observe nearly overhead. In this case, the maximum Doppler shift, or change in the color of the hydrogen emission caused by motion toward the observer, is seen.

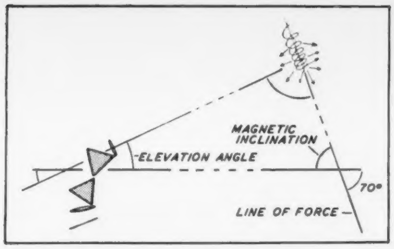
If, however, we look to the north a few degrees above the horizon (at the so-called magnetic horizon), the hydrogen emissions are not shifted toward the blue but are merely broadened, both toward the red and the blue. This broadening is also a Doppler effect, apparently arising because the protons are not moving in straight lines parallel to the magnetic field, but are spiraling. This gives the protons at the magnetic horizon a small amount of motion toward the observer and then a small amount away, although the predominant speed is down the lines of force.

The problem is to construct a system of trajectories for these particles that will be consistent with all three types of observed data. At present, in order to reconcile all the observations, it seems necessary to have the particles entering with a large variety of spiral orbits rather than with only one type. If we think of the protons coming into the atmosphere along the magnetic lines of force and describing the ridges of a screw with a certain pitch, then some of the particles will follow a very flat pitch, some a very elongated one.

We can now ask the question: If the particles start from several earth radii or more away, what will be the distribution of pitch angles when the particles get near the earth? This problem can be solved for individual protons, and the distribution of pitch angles that is obtained is consistent with what seems to be required to explain the hydrogen-line profile on the magnetic horizon.

To explain the profile in the magnetic zenith, as well as the luminosity curve, it now seems necessary to suppose that all the particles do *not* enter the atmosphere with the same speed. A few of them move several thousand miles per second and are thus able to reach the lower auroral levels of the atmosphere. But many others are apparently traveling at much lower speeds — only a few hundred miles per second or less.

This interpretation of the hydrogen emission, if true, suggests that the protons are accelerated in the neighborhood of the earth. A wide spread in velocities is inconsistent with the idea of *direct entry* into the atmosphere of particles ejected by the sun and traveling nearly identical paths through space, for they would then not all arrive at the earth at the same time and would not be expected to enter the atmosphere at the same place.



The broadening of hydrogen lines in auroral spectra in different parts of the sky may be caused by spiral motions of incoming protons along the lines of force of the earth's magnetic field. Diagram by L. Vegard.

An alternative explanation of the velocity spread may be possible if the protons and electrons travel from the sun to the earth in a magnetized cloud. There is some theoretical, and lately some observational, basis for supposing that solar gas clouds do contain a small but significant magnetic field. In this situation, individual particles may circle the magnetic lines of force in the cloud with a variety of speeds, some much higher than the speed of the cloud as a whole as it moves outward from the sun.

The spread in velocities will mean, of course, that there is some time delay between the entry of the fast particles and slow particles, the amount of delay depending on how far from the earth the particles are accelerated or released from the magnetized cloud. If the change takes place at a distance of only a few earth radii, then the time delay would be just a few seconds between the fastest and slowest particles. Yet it may be possible to observe even this small a delay, for the fast particles would penetrate deep into the atmosphere and the slower ones would radiate only at higher levels.

The role of electrons in the aurora. Whatever the origin and nature of protons in the aurora, it is fairly definite that they are not the entire story. The brightness of hydrogen light, compared with nitrogen and oxygen emissions, may vary markedly among different aurorae. It seems on the whole that the arc forms, especially homogeneous arcs, have the strongest hydrogen lines, with rayed draperies and rayed arcs usually showing much fainter hydrogen.

There also seems to be some dependence of the hydrogen intensity on the latitude at which the aurora is seen. At low-latitude stations, such as Yerkes Observatory in southern Wisconsin, the hydrogen lines may be quite strong compared with those observed over Saskatoon, Saskatchewan; Fairbanks, Alaska; or Tromsö in northern Norway. If protons were the only cause of the aurora, and if aurorae at all locations occurred at about the same height in the atmosphere, the hydrogen emission would be about the same strength, compared with the oxygen and nitrogen lines, in spectra at all latitudes. Since this is not the case, other types of excitation seem to be important.

Another possible means of producing auroral light is by electrons that enter from outside the atmosphere. These electrons will not emit a characteristic line spectrum, and their presence has to be inferred from indirect arguments. While a proton can capture an atmospheric electron to form hydrogen, an electron can only excite radiation of the atmospheric constituents.

If we associate incoming electrons, predominantly, with the rayed forms of the aurora, we are again led to the conclusion that these particles must possess a wide dispersion in their velocities outside the atmosphere. A single electron striking the atmosphere at a particular speed would produce radiation in a fairly shallow height range. Thus, the extremely long rays, which may stretch for over a hundred miles in height, would require a large spread in incident velocities.

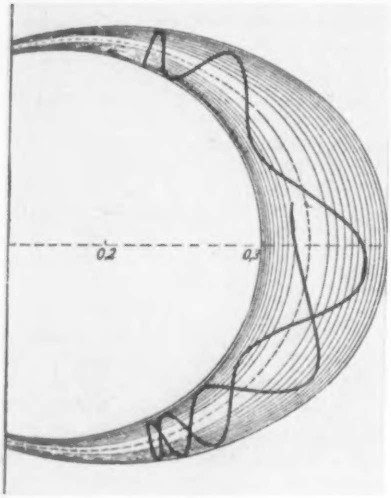
An alternative mechanism for producing these long rays is an electric discharge (the same general type of process that activates neon advertising signs). A stream of electrons goes through the gas, being accelerated by an electric field. If this mechanism is operative in the aurora, the question is: What is the source of the electric field?

In the high layers of the atmosphere, where the aurora occurs, there is an abundance of electrons at all times. In fact, this region is known as the ionosphere, because there is always present a certain amount of ionization or separation of electrons from the parent molecules. If an electric field is applied, these electrons will be speeded up. It is not sufficient, however, just to set a static electric field above or below the ionosphere, as the electrons would then simply be displaced a small amount until the separation of positive and negative particles exactly balanced the impressed electric field.

What is required is a more dynamic picture, with a steady current being set up through the ionosphere, or with a fluctuating electric field being applied. Each of these possibilities seems feasible, but so far only a simplified theory for the first one has been developed. If the electrical circuit is to be closed through the atmosphere, the current may pass from the highest regions down to the lower ionosphere. Thence it may be conducted east or west in this region of relatively high density to another point, where it may flow back up into the interplanetary medium.

On the other hand, a fluctuating electric potential may be set up close to the earth by positively charged protons that

come in just above the atmosphere and then are unable to get closer. Such charged particles moving in the earth's magnetic field may experience a phenomenon known as *magnetic reflection,* wherein the particles move along the field to a point where the lines of force become so crowded together and the field so dense that the particles have insufficient energy to squeeze through. At this point they are reflected back whence they came. The particles may in this fashion travel back and forth between the Northern and Southern Hemispheres without actually striking the atmosphere and being slowed down.



The heavy curve is the path of a proton (or electron) trapped by the earth's magnetic field, whose lines of force, represented by the thin curves, extend from a region on the earth's surface in the Northern Hemisphere to the corresponding region in the Southern. The particle will oscillate until a collision with another particle changes its orbit. As it moves among the converging lines of force, its orbit becomes more tightly looped. From "The Aurorae," by L. Harang, Chapman and Hall, Ltd., London, 1951.

But it must be emphasized that these matters are still highly speculative. They are reviewed here only to show the directions in which we are working to find the answers.

This is the present status of the problem. It is hoped that we can tell you in a few years time that the situation has become greatly clarified. Further details of these topics and a list of references to the literature will be found in an article by the author on "Theories of the Aurora" in *Advances in Geophysics,* Academic Press, Vol. 4, 1958, pages 109-215. Some of the work reviewed here is being supported by the Air Force Cambridge Research Center under contract AF 19 (604)-3044 with the University of Chicago.

NEWS NOTES

NATIONAL OBSERVATORY TO BE ON KITT PEAK

A 70-acre flat area on the summit of a 6,875-foot mountain in the Quinlan Mountains, about 40 miles southwest of Tucson, Arizona, has been chosen for the new National Astronomical Observatory (*Sky and Telescope,* August, 1957, page 482). There an 80-inch reflector will be erected.

This selection of Kitt Peak, in the Papagos Indian Reservation, culminates a three-year study by a team of astronomers of some 150 sites in the southwestern United States. The search had narrowed down to three locations in Arizona, where extensive tests of the seeing were conducted.

AURA, Inc., the association of universities responsible for building and operating the observatory, has a new member – Yale University – in addition to the seven institutions listed on page 181 of the February issue.

POSSIBLE SOURCES OF A LUNAR ATMOSPHERE

Recently a very sensitive test for a possible atmosphere on the moon was carried out at Cambridge, England (*Sky and Telescope,* November, 1957, page 12). An occultation of the Crab nebula by the moon was observed by B. Elsmore with a radio telescope, and was found to have a duration slightly shorter than predicted from geometrical considerations.

This discrepancy might be attributed to refraction of the radio waves from the Crab nebula by electrons in a highly rarefied lunar atmosphere – not more than about 10^{-13} times the sea-level density of the earth's atmosphere. However, the observed effect was of the same size as the errors of observation, and actually provides only an upper limit to the amount of a possible lunar atmosphere.

In the February 14th issue of *Science,* W. F. Edwards, California Institute of Technology, and L. B. Borst, New York University, discuss the properties and possible origin of gases above the surface of the moon, on the assumption that such a lunar atmosphere has a density of about 10^{-13} the earth's. At so low a density, a molecule could travel some 600 kilometers, on the average, before colliding with another one, but most of the lunar gas would be in a layer less than 10 kilometers thick, so collisions with the lunar surface itself would predominate. The kinetic temperature of the gas would be that of the lunar surface, which reaches 135° centigrade at lunar noon.

Because the escape velocity at the moon's surface is only 2.37 kilometers per second (compared to 11.2 on the earth), gases of low molecular weight, such as oxygen and nitrogen, could not be retained. According to G. P. Kuiper, gases of molecular weight less than 60 would be lost during the heat of the lunar day. Among heavier substances, Mr. Edwards and Dr. Borst propose that the rare, inert gases krypton and xenon might form a lunar atmosphere.

One mechanism for producing them is the spontaneous decay of uranium 238 in the surface layers of the moon. H. C. Urey has estimated that the moon's uranium content is about 0.012 part per million by weight, with possible enrichment by a factor of two at the surface. The main constituents of the resulting gas would be xenon isotopes of mass 132, 134, and 136, with a five-per-cent admixture of krypton.

A second process is radioactive decay of iodine 129, which would produce a gaseous envelope consisting solely of xenon 129. This mechanism would require the outgassing of the moon's surface layers, probably by the stirring up caused by meteorite impacts, for a period at least as long as the half life of iodine 129, which is about 17 million years.

If these or other possible processes for producing krypton and xenon did not operate, however, it is possible that these gases are the remnants of those trapped in the moon's mantle at the time of its formation. As inert gases, they do not enter into chemical combination with other elements. Again, stirring by meteorite impacts would release the gas from the moon's solid layers. The main atmospheric gas would then be krypton, with only seven per cent xenon.

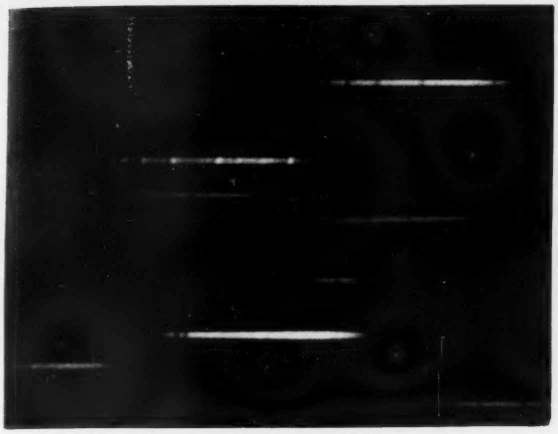
If the moon actually has an atmosphere of the amount assumed by Mr. Edwards and Dr. Borst, it may eventually be possible to distinguish among these three possibilities by analysis of gas samples. They point out, however, "Since the scale height [of the lunar atmosphere] is only a few kilometers, it is not probable that initial grazing rocket orbits would come sufficiently close to permit the collecting of a gas sample."

DINSMORE ALTER RETIRES

On April 1st, Dinsmore Alter retired from the directorship of the Griffith Observatory and Planetarium, Los Angeles, California. He served in this capacity for 23 years.

Dr. Alter is well known as a popularizer of astronomy and as the editor of the *Griffith Observer.* He is a recognized authority on lunar matters who has taken moon photographs of exquisite quality with the 60-inch reflector at Mount Wilson. Dr. Alter's professional interests have also included the statistical analysis of variable star light curves and of meteorological records.

At the Western Amateur Astronomers convention this August, he will be given the G. Bruce Blair award for his contributions to amateur astronomy.



In the Schmidt-camera picture at the right, the nova in Ophiuchus is marked by a southward-pointing arrow. The K-type star HD 159309 is the brightest, its two strong violet lines of calcium showing in the spectrogram at the left. In the upper right is an A-type star, with the Balmer series of hydrogen absorption lines. The nova's spectrum shows these same lines as bright. Photos from Mexican National Astrophysical Observatory.

NOVA IN OPHIUCHUS

On March 20th, the Harvard Observatory clearinghouse for astronomical news was notified of the discovery of a nova in Ophiuchus, by Guillermo Haro at the Tonanzintla Observatory, Puebla, Mexico. The new star was first found by Dr. Haro while examining a 3-inch Ross camera plate secured six months earlier as part of a general nova-search program in the central part of the Milky Way galaxy.

In photographs taken last August of the same region of the sky, there is no trace of this object. It was of the 10th magnitude on the discovery plates, and by November 18, 1957, reached a maximum brightness of 8.0. This is distinctly a "slow" nova, and on March 19th it was still as bright as magnitude 10.5. Its position is $17^h\ 31^m.4$, $-28°\ 08'$ (1950 co-ordinates), not far from the 9th-magnitude star HD 159309, as shown on the accompanying photograph.

NEW PENCIL-BEAM ANTENNA FOR RADIO ASTRONOMY

A major problem in radio astronomy is obtaining adequate resolution at long wave lengths. To separate two neighboring radio sources, the size of the antenna must be increased in proportion to the wave length used. This need has caused the building of giant interferometer systems such as the 1,500-foot Mills cross in Australia.

At the Cavendish Laboratory, Cambridge, England, a new "moving-T aerial" has been built, with the same resolution as an equivalent-sized Mills cross but requiring much less construction. As in the Mills cross, there is an east-west array, but the north-south arm is replaced by a small movable antenna that can be set at various wave spacings from the main antenna. In practice, 38 such settings are made in observing a single place on the sky.

With this system, more than half the sky has been mapped at a wave length of eight meters (38 megacycles). The width of the antenna's pencil beam is 2.2 degrees at this wave length. One difficulty with an instrument of this design, however, is that the complicated reductions of the data call for a large electronic computer.

The new interferometer system, which was designed by J. H. Blythe, is described by him in the *Monthly Notices* of the Royal Astronomical Society, Vol. 117, No. 6, 1957.

IN THE CURRENT JOURNALS

ANTI-MATTER, by Geoffrey Burbidge and Fred Hoyle, *Scientific American*, April, 1958. "Anti-matter may exist in our galaxy, but it cannot exceed about one part in 10,000,000 of ordinary matter if it is there. It is most unlikely that any of the stars in our galaxy can be made of anti-matter."

ON THE "COLOR INDEX" OF METEORS, by L. G. Jacchia, *Astronomical Journal*, December, 1957. "For meteors fainter than photographic magnitude -1.5 (visual magnitude about zero) a difference of 1.0 mag. in the photographic magnitudes of meteors corresponds to a difference of only 0.65 mag. in the visual magnitudes."

PLANETARY TEMPERATURES

For any investigation of the physical condition of the planets, we need to know their surface temperatures. Improved techniques have recently come into use for measuring the weak thermal radiation of each planet. A sensitive infrared detector, such as a Golay cell, is placed at the focus of a telescope, with filters to cut off reflected solar radiation of wave lengths shorter than about eight microns. Improved accuracy is obtained by chopping the planetary radiation with a rotating shutter and using a.c. amplification of the thermocouple output.

Such new developments, in the hands of W. M. Sinton, Lowell Observatory, and John Strong, Johns Hopkins University, mark a considerable advance over the pioneer measurements of planetary temperatures made in the 1920's. These were by W. W. Coblentz and C. O. Lampland, at Lowell Observatory, and E. Pettit and S. B. Nicholson, at Mount Wilson Observatory.

In *Leaflet* 345 of the Astronomical Society of the Pacific, February, 1958, Dr. Sinton has given a new compilation of planetary temperature data, from which the accompanying table is taken. Both computed and measured temperatures are listed, all on the centigrade scale.

In the cases of Venus, Jupiter, Saturn, Uranus, and Neptune, the calculated temperatures are for the equator of a rapidly rotating planet that cannot exchange heat between different latitude zones. For Mercury and Pluto, the computation is for a plane surface perpendicular to incoming solar radiation. The calculated temperatures of the moon and Mars are based on the theory of surface heat conduction, neglecting the effects of any atmosphere.

Dr. Sinton points out that further temperature measurements are needed, especially for the remoter planets, as so little thermal radiation is received from them that observations are very difficult. Neptune and Pluto are probably too cold and too distant for present techniques.

CENTIGRADE TEMPERATURES OF THE MOON AND PLANETS

Planet	*Calculated*	*Observed*	*Observers*
Mercury, subsolar point	+352°	+337°	Pettit and Nicholson
Venus, center of half-lit disk	−30°	−39°	Strong and Sinton
Moon, center of disk at full	+114°	+118°	Pettit and Nicholson
Moon, center of disk at new	−170°	−153°	Pettit and Nicholson
Mars, hottest point	+30°	+30°	Strong and Sinton
Mars, sunrise near equator	−108°	−70°	Strong and Sinton
Jupiter, subsolar point	−164°	−143°	Coblentz and Lampland
Saturn, subsolar point	−193°	−145°	Coblentz and Lampland
Uranus, subsolar point	−221°	−170°	Coblentz and Lampland
Neptune, subsolar point	−231°	———	———
Pluto, subsolar point	−213°	———	———

American Astronomers Report

Here are highlights of some papers presented at the 99th meeting of the American Astronomical Society at Indianapolis, Indiana, in December, 1957. Complete abstracts will appear in the Astronomical Journal.

Southern Stars of High Velocity

Stars that appear to have high space velocities are of special importance, since they are the same kinds of object as those making up the central bulge of our Milky Way galaxy. Nancy G. Roman, Naval Research Laboratory, had recently published an extensive catalogue of these stars that are brighter than visual magnitude 9.5 and north of declination −20°, but very little information has hitherto been available about southern stars of this class.

At the Mt. Stromlo Observatory in Australia, William Buscombe and Pamela M. Morris have now compiled a finding list of 1,315 probable high-velocity stars in the southern sky. They began by computing the motions of all stars south of the celestial equator for which reliable trigonometric parallaxes were known. The stars put into the list were those whose space velocities, relative to the solar neighborhood (corrected for the sun's motion toward Hercules), exceed 60 kilometers per second.

A star's space motion, however, is made up of two components, its radial velocity (along the line of sight) and its tangential velocity (at right angles to the line of sight). The Australian astronomers included in the list stars for which only one velocity component is known, if it exceeds 50 kilometers per second. There are very few determinations of radial velocity for faint southern stars, so they were further obliged to use large proper motion (greater than 0.5 second of arc per year) as a sole criterion in many cases.

Of the 1,315 stars, there is complete information—trigonometric parallax, proper motion, and radial velocity—for only 18 per cent. Proper motions are available for nearly all of them, reliable trigonometric parallaxes for about half, and radial velocities for one-third of them. Nearly half of the stars in the list are fainter than magnitude 10, and about one in every 25 is a known variable star, generally of the long-period or red semiregular type.

Several southern observatories are cooperating to provide new data on high-velocity stars. At the Cape Observatory in South Africa, photoelectric magnitudes and colors, parallaxes, and proper motions are being measured. The 74-inch reflectors at the Radcliffe and Mt. Stromlo observatories are being used to obtain spectral classifications and radial velocities. Also at Mt. Stromlo, the Yale-Columbia southern station has a program of measuring proper motions and parallaxes. The observatories at La Plata and Cordoba, in Argentina, are contributing radial velocities and proper motions; further proper motion work is being done at the Sydney Observatory, Australia. This widespread collaboration should greatly increase our knowledge of high-velocity stars in the southern hemisphere of the sky.

Spectral Variations of HD 20336

A star of spectral type *Be* is hot, blue, and has bright lines of hydrogen in its spectrum. These emission lines originate either in an extensive atmosphere surrounding the star, or perhaps in a lens-shaped cloud rotating rapidly in the star's equatorial plane. The Doppler effect of the rotational velocity (200 to 300 kilometers per second) widens the bright lines, but these are bisected by narrower, dark absorption lines, produced by the outermost gases on the side of the cloud nearer to the observer.

Thus, the bright lines apparently have two components, one on the violet side of the central absorption, the other on the red side. A number of *Be* stars show no change year after year in this emission-absorption structure, which evidently represents a very stable ring or cloud. Other such stars show what is called V/R variation – the relative intensity of the bright components of each hydrogen line varies with time.

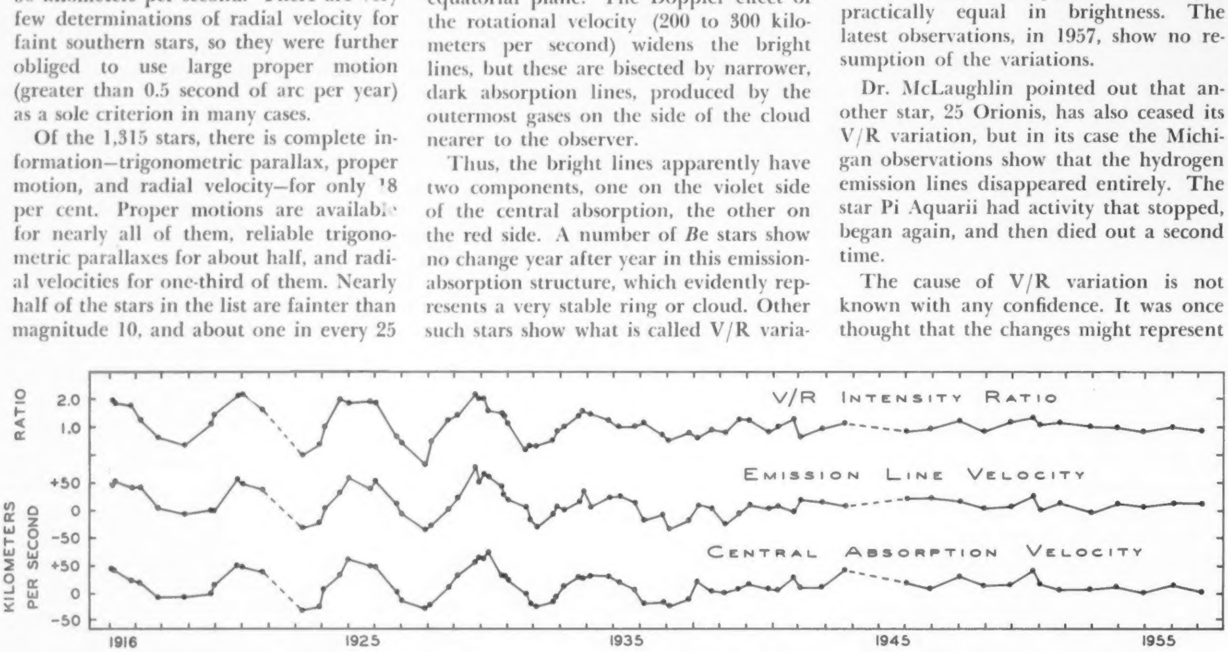
Dean B. McLaughlin, University of Michigan Observatory, reported on a 40-year series of spectrograms of one of these V/R variables, the 5th-magnitude star HD 20336, located at $3^h\ 15^m.6$, +65° 28′ (1950), near the boundary between Cassiopeia and Camelopardalis.

Until 1932, the variation in relative brightness of the V (violetward) and R (redward) components followed a fairly regular period of roughly 4½ years. During this cycle, the hydrogen line as a whole shifted to longer wave lengths when the V component was stronger. When the R component was most intense (V/R ratio less than 1), the pattern as a whole was shifted to the violet by a similar amount (velocity change about 50 kilometers per second). But the absorption remained practically central in the emission line, and the width of the latter did not change appreciably.

After 1932, however, the star failed to hold to this pattern of cyclic behavior. The ranges in velocity and in intensity ratio both diminished, while the emissions faded. About 1937 the variations practically ceased, and since then the velocity has remained near its average value and the emission components have stayed practically equal in brightness. The latest observations, in 1957, show no resumption of the variations.

Dr. McLaughlin pointed out that another star, 25 Orionis, has also ceased its V/R variation, but in its case the Michigan observations show that the hydrogen emission lines disappeared entirely. The star Pi Aquarii had activity that stopped, began again, and then died out a second time.

The cause of V/R variation is not known with any confidence. It was once thought that the changes might represent



In the middle curve, the variations of the velocity of approach (−) and recession (+) for hydrogen emission features of HD 20336 are shown. The lowest curve is for the central absorption line only, while the uppermost line shows the ratio in intensity of the violet emission component to the red one. From about 1937 onward the fluctuations have practically died out. University of Michigan Observatory diagram.

alternate expansion and contraction of the atmosphere or equatorial ring, but improbably large dimensions would be required. Dr. McLaughlin thinks it more likely that gas is continuously being shed from the envelope or ring at the star's equator, and that the variations represent changes in both the amount and speed of the material streaming out into space.

Origin of Rapidly Rotating Asteroids

Some five years ago, G. P. Kuiper proposed that the asteroids, as well as the principal planets, originated as condensations in a primordial solar nebula, and grew by the accretion of material. More recently, Eugene K. Rabe, of the Cincinnati Observatory, has critically examined the consequences of this hypothesis to find whether it can account for the observed properties of the minor planets, such as the rapid rotations some of them possess.

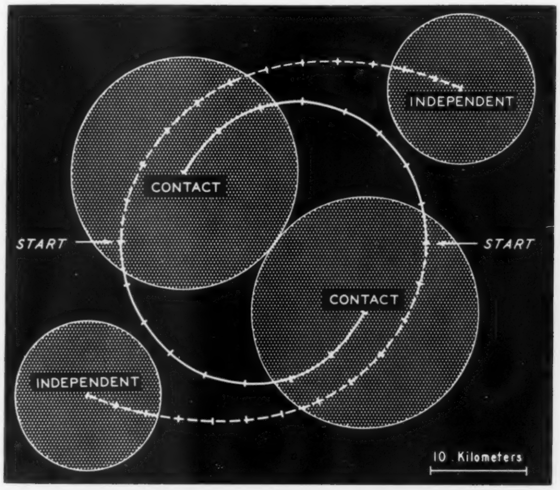
According to Kuiper's formulation, the original *protoplanets* developed cores of solid material surrounded by gaseous envelopes. In the case of the small but numerous asteroid condensations, the envelopes were probably more than 100 times as large as the cores. Dr. Rabe reported his study of a hypothetical case of two such bodies, moving around the sun in independent but nearly parallel paths, and undergoing a close encounter. Would they capture each other to form a double asteroid, as a result of friction between their envelopes?

As a criterion for the stability of such a double body, Dr. Rabe postulated that the mutual attraction of two small spheres (of density twice that of water) would have to be equal to or greater than the individual attraction of the sun for each component. In order for a stable binary to form at a distance of three astronomical units from the sun (where asteroids are most numerous), the minimum radius of each body would have to be 4.7 kilometers. However, at Jupiter's distance, where the Trojan asteroids are located, radii of 1.6 kilometers would be sufficient, because the disruptive effect of the sun's attraction would be much less.

Once such a binary system had formed, continued friction between the two envelopes would reduce their relative velocity and they would tend to spiral inward toward one another. Mass accretion would also hasten their coalescence to form a single body rotating with the period of relative orbital motion just before final contact between them. This period was found to be somewhat longer than 4.7 hours, regardless of the solar distance of the particular asteroids involved.

A body formed by such a process should have a distinctly elongated shape. This would account for the rhythmic light variations of many of the bright minor planets, such as Eros, changes long ago recognized as due to rotation. The actual shortest observed periods of such light fluctuations are close to 4.7 hours (*Sky and Telescope,* March, 1953, page 129).

To test the validity of the hypothesis, Dr. Rabe has calculated by numerical integration the history of a pair of spherical condensations, each 10.58 kilometers in radius and of density 2.0, revolving around each other in circular orbits at a distance apart of 31.74 kilometers, corresponding to the assumed approximate limit of stability. Their solar distance was taken as three astronomical units.



The Rabe calculation was based on the intervals shown in this diagram, where the ticks denote $21\frac{3}{4}$-minute intervals in the fictitious model. As the condensations increase in mass they spiral together and coalesce. Going backward in time from the points labeled "start," the bodies are found to have originally been moving independently. For computational purposes, the masses were assumed to increase by five per cent in each interval. Cincinnati Observatory diagram by E. K. Rabe.

In order to obtain the essential features of the orbital changes quickly and without a prohibitive amount of computing, Dr. Rabe assumed that the masses of the condensations increased with time at a fictitiously rapid rate. In the diagram, the change of mass is indicated by the sizes of the circles that show the geometrical cross sections of the two spheres. While this fictitiously rapid orbital development is convenient, and shows that coalescence would actually take place, such a pair of bodies would actually complete many mutual revolutions between the times of capture and final contact.

From the time labeled "start" in the diagram, Dr. Rabe computed backward, to find that a mass loss by a factor of about two leads to instability and to dissolution of the pair, whereas a mass increase by a factor of about 1.5 would be sufficient to cause inward spiraling and the formation of one combined body. Its rotational period would be 4.7 hours, in excellent agreement with the theoretical conclusion.

Since the period of revolution of a binary asteroid depends, by Kepler's third law, only on the mutual distance and on the values of the masses, it does not matter whether the two components are finally brought to contact by a gradual mass accretion, or by friction between their gaseous envelopes.

Artificial Satellite Temperatures

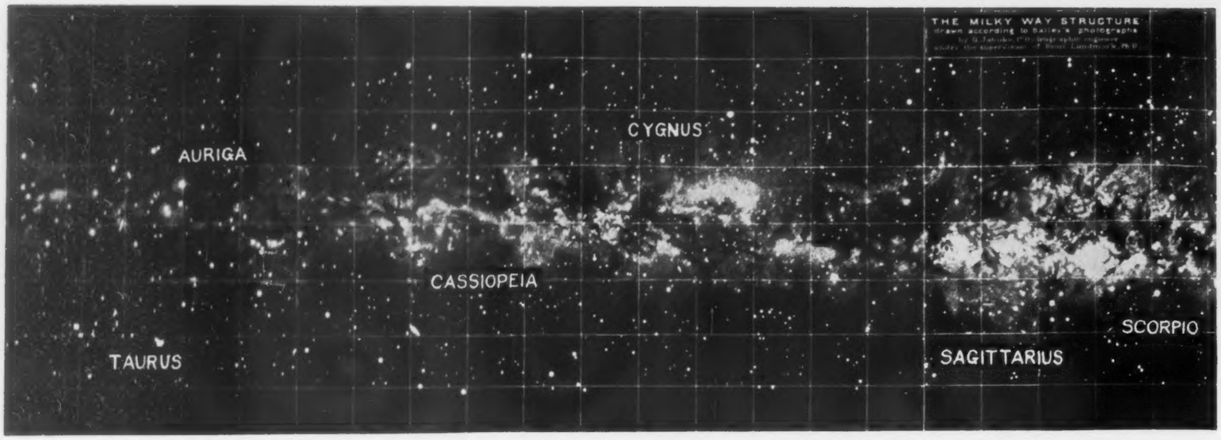
The range of temperatures for a close earth satellite has been evaluated theoretically by Raymond H. Wilson, Jr., of the Naval Research Laboratory, using formulae derived from the well-known laws of radiation. Practically all the heat exchange must be by the absorption and re-emission of radiant energy — predominantly solar radiation.

The sun's heat would give an average temperature of $+8°$ centigrade to a perfectly absorbing satellite that spent 80 per cent of the time in sunlight. This would be the temperature of the protected interior; the surface would vary from about $+22°$ or more when the satellite was in sunlight to $-6°$ or lower when it was in the shadow of the earth.

Dr. Wilson has also computed the effect of solar energy reflected from the earth and of the heat radiated by the earth. They turn out to be minor influences, raising the average temperature of the satellite by about four degrees. For these combined effects, Dr. Wilson adopts an average temperature value of $F^{\frac{1}{4}} \times 300°$ Kelvin, where F is the fraction of time the satellite is in sunlight.

The foregoing temperatures hold only if the satellite is an idealized "black body." The nature of its surface has a great effect. For example, inside a shell of typical aluminum alloy continuously in sunlight, the mean temperature could be as low as $-42°$ centigrade if the surface has been coated with silicone, or as high as $+117°$ if the surface is clean and polished. Evidently, the temperature of the satellite can be held close to any desired value in this range through suitable finishing of its exterior.

All Dr. Wilson's predictions depend upon the assumption of 6,150° Kelvin for the effective temperature of the sun. An improvement on this value could result, he suggests, from the temperatures reported by actual satellites.



The Milky Way from Taurus to Scorpius, drawn under the supervision of Knut Lundmark, Lund Observatory.

GETTING ACQUAINTED WITH ASTRONOMY

THINGS TO OBSERVE IN THE SKY — II, *by Edward G. Oravec*

IN MARCH, when this department was started, we talked about simple constellation study. Now we turn to the host of attractive objects to be found in the heavens.

THE MILKY WAY, STAR CLUSTERS, AND NEBULAE

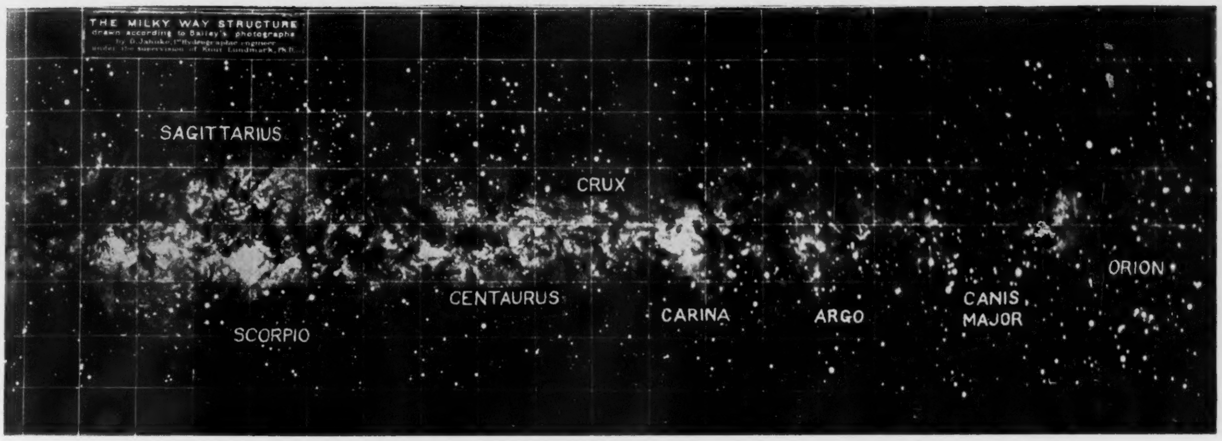
Extending completely around the sky, from Cepheus and Cassiopeia in the north to Crux and Centaurus in the south, is the hazy irregular band of light known as the Milky Way. It lies along the principal plane of our flattened, spiral-shaped system of stars, and is itself composed of millions upon millions of stars, interspersed with vast clouds of dust and gas, some dark and obscuring, some luminous.

The great starclouds of the Milky Way may be studied best on clear, moonless nights when stars to the 5th magnitude are readily discernible to the naked eye. It is then that the Milky Way, with its bright patches and dark rifts, can be appreciated in all its splendor. It is most spectacular in the constellations of Sagittarius, Scorpius, Ophiuchus, and Cygnus, for mid-northern observers, while in Orion and Monoceros it is inconspicuous. Therefore, the Milky Way as seen in the summer and fall of the Northern Hemisphere is superior to its appearance in winter and spring, in brightness, extent, and complexity.

Without optical aid, several important star clusters may be found by an observer

The constellation of Orion, photographed with a simple condenser lens by Philip C. Fisher. The belt stars run diagonally across the center; below them, in the sword, a fuzzy patch is the Great Nebula in Orion, easily observed in a small telescope. (See page 353.)

A Harvard Observatory photograph of the Milky Way in Cygnus.



The Milky Way from Sagittarius to Orion. The grid lines mark galactic latitude and longitude.

who knows their respective constellations. In Taurus are the Hyades and the Pleiades, two of the nearest and brightest of the open or galactic clusters. In Cancer is Praesepe, the Beehive, while along one side of the Keystone in Hercules lies a globular cluster, M13, the light of which takes some 30,000 years to reach us; this cluster looks like a hazy star of the 5th magnitude (see page 356).

The prefix M indicates an item in the catalogue of some 100 nebulous objects compiled by Charles Messier nearly 200 years ago. He labeled the great gaseous nebula in Orion's sword with No. 42, and the spiral galaxy in Andromeda, one of our neighbors, No. 31 (see page 354). Both of these objects may be discerned without optical instruments.

Binoculars aid considerably in studying fainter constellations and small groups of stars, especially from towns and cities where the stars appear dim in a bright sky. Powers ranging from 6x to 10x are perhaps best, and these instruments can be held by hand; more powerful binoculars should be mounted sturdily. Inexpensive imported binoculars are easy to obtain. They should be of the prism type, giving fields of six or seven degrees. Field glasses or opera glasses of the Galilean type have rather small fields of view for astronomical purposes.

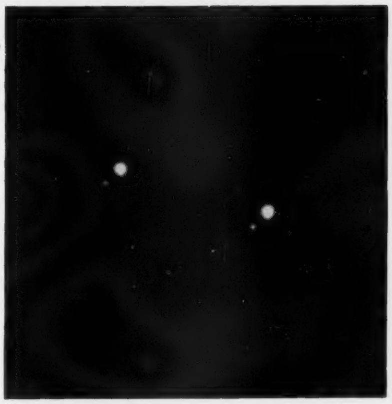
With such optical aid, one obtains the best views of the Hyades and Pleiades clusters and notices the greenish color of the Orion nebula. The Beehive, M35 in Gemini, and the Double Cluster in Perseus may be resolved into stars. Binoculars improve the appearance of M31 and brighten M13, but globular clusters and galaxies are, in general, telescopic objects.

Double Stars

A large fraction of the stars are double or multiple, although appearing as single objects to the unaided eye. Most of them are binaries, physically associated pairs in which the components revolve around each other in periods of from about five hours to many thousands of years. Some pairs are so close together they can never be seen double, even in the most powerful telescopes, but others are farther apart and may be separated in instruments usually used by amateurs.

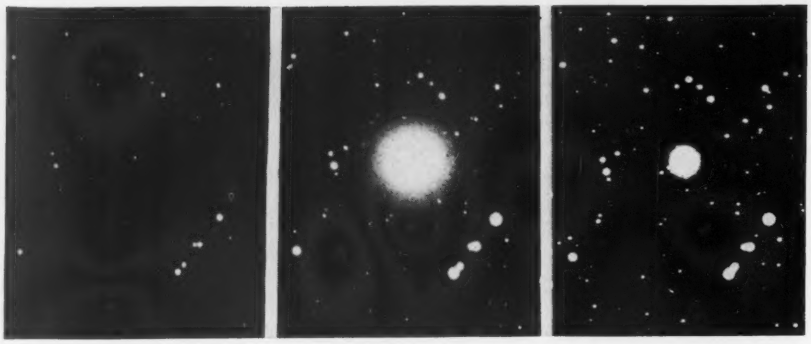
Many thousands of visual double stars have been catalogued, and convenient lists of them are available. Small telescopes will show Mizar, the star at the bend in the handle of the Big Dipper, to be double. (Near Mizar is also a 5th-magnitude companion, Alcor, that anyone with normal eyesight should see easily.) Binoculars will show that Epsilon Lyrae is double, and a good 3-inch refractor will just separate the components of each star of the wide pair — this is a quadruple system. Albireo, the star at the foot of the Northern Cross, is an easily observed pair whose components contrast beautifully in blue and gold.

Observing books like Olcott's and Norton's give lists of double stars of varying



Owners of small telescopes find the double star Mizar, where the Big Dipper handle bends, easy to resolve into its two bright components, 14.6 seconds of arc apart. This early Harvard photograph has two sets of images.

Without a telescope, most observers see the easily identified Pleiades cluster in Taurus as a small dipper. Binoculars or a low-power telescope show it as a field of brilliant diamonds, the six brightest being named (left to right) Atlas, Alcyone (Eta Tauri), Merope, Maia, Electra, and Taygeta. This picture was made by Luc Secretan, Washington, D. C., on December 8, 1955, using a 2-inch long-focus lens, exposure 10 minutes on Tri-X film. Here north is at the top as seen in binoculars; an astronomical telescope would invert this view.



Three main phases in the history of RR Pictoris, which was originally of apparent magnitude 12.7 (left), but became a nova in 1925 (center) reaching magnitude 1.2. At the right it has begun to fade back to obscurity, a process taking many years. This star is also called Nova Pictoris 1925.

difficulty. The major considerations are the apparent distance between the components of each double and their relative brightnesses. Stars of magnitude between 3 and 6 and only 20 seconds of arc (20″) may be readily resolved with low power. When the magnitudes differ considerably, either a greater power must be used or the separation of the stars must be larger for them to be seen individually.

The serious double star observer should consult such works as Aitken's double star catalogue, where observations of each pair over the years are listed. The apparent separations of many binaries change while their components revolve. What may have been an easy binary 20 years ago may be very difficult to observe as double now, and vice versa. For this reason, observing lists of selected stars should generally be taken only from recent compilations.

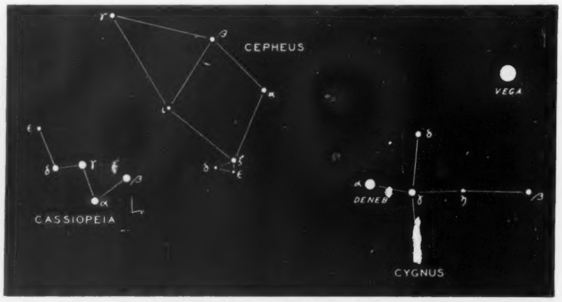
Without special equipment, such as a double-star interferometer or a filar micrometer, and a well-mounted telescope, the average amateur cannot expect to contribute much of scientific value in this field. Observing double stars is interesting, however, even with instruments of low power, and much information of an astronomical nature may be obtained. Double stars are usually considered the best objects with which to test the quality of a telescope lens or mirror.

Variable Stars

This is a field in which amateurs make a valuable contribution to astronomy. With only the most elementary instructions and simple equipment, many variable stars may be studied. Even to the naked eye, there are a dozen or two within range, but with 8-power binoculars several hundred variables may be seen.

A variable star is one that changes in apparent brightness. Some of them are double stars that revolve in a plane lying close to our line of sight; therefore, at regular intervals one star may pass in front of the other, producing a partial or total eclipse, temporarily reducing the combined light of the pair. These double stars are also called eclipsing variables. Amateurs may derive much pleasure and experience from following some of them, such as Beta Lyrae and the famous star Algol, in Perseus. An eclipse of the latter star requires nine hours to transpire and reduces its brightness to about one-third; these eclipses occur every 2 days, 20 hours, and 48 minutes.

This key chart shows the location of Delta (δ) Cephei, the first known of the Cepheid variables. It is the star from which the class received its name.

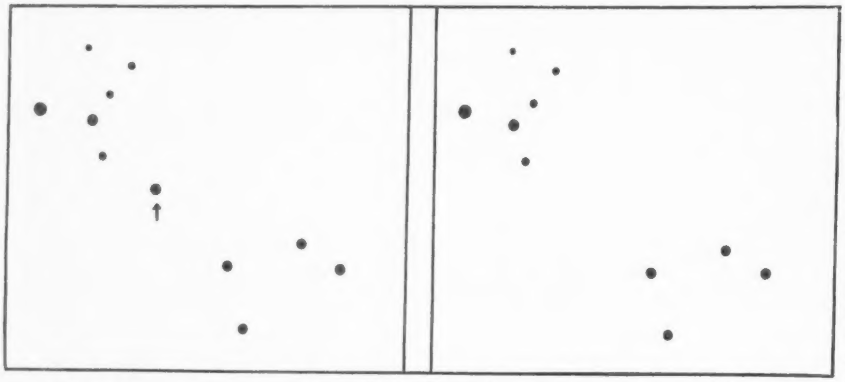


Stars whose brightness fluctuations are intrinsic may be divided into three classes: Cepheid, long-period, and irregular variables. In the first class, the magnitude variations and periods may be determined with great accuracy; these are rapidly pulsating stars with periods ranging from a couple of hours to several weeks. Delta Cephei, the prototype of this class, and Eta Aquilae are the best-known naked-eye Cepheids for northern observers. Lists of bright variables of all kinds may be found in observing books.

The two other classes, long-period and irregular variables, are the particular concern of the American Association of Variable Star Observers (AAVSO). There are over 100 long-period variables that are brighter than 9th magnitude at maximum, which means they are at times visible in binoculars and are well observed in a 3-inch telescope; many irregular variables are at least this bright. Mira, in the constellation Cetus, is the best known of the long-period variables, changing from about the 9th to the 3rd magnitude and back again in roughly 11 months. A famous irregular variable is Betelgeuse, the red 1st-magnitude star in Orion's shoulder.

Another program relating to variables is the search for novae, stars that suddenly become conspicuously bright and then gradually fade to obscurity. Such "new stars" usually appear in the Milky Way, and to scan there systematically with the naked eye, or to scrutinize small Milky Way areas with binoculars, constitutes a program of observing that many find of great interest. A nova search program for amateurs is conducted by the AAVSO, from whom information concerning it may be obtained. Amateur astronomers should write to the Director, AAVSO, 4 Brattle St., Cambridge 38, Mass., for instructions on variable star observing.

(To be continued)



When the famous long-period variable, Mira, is near its maximum brightness, about 3rd magnitude, the constellation of Cetus looks as at the left, but at minimum Mira disappears from naked-eye view, as at the right. The variable's period averages about 330 days.

Amateur Astronomers

Astronomical League Convention Notes

REGISTRATION is open for the general convention of the Astronomical League, to be held at Cornell University, Ithaca, New York, July 3-6. Until May 31st, the registration fee will be $1.00 per person; from June 1st, $2.00 each person and $3.50 per family.

Remittances should be mailed to Stephen Weber, 302 Beresford Rd., Rochester 10, N. Y. He will also accept reservations for the convention banquet at $3.75 per person.

Housing accommodations in the university dormitories may be secured from Mr. Weber at $4.00 a night for one person in a room, $5.00 for two persons in a room.

Thursday, July 3rd, will be devoted to registration, the setting up of exhibits, and informal gatherings. The convention will open at 10:30 Friday morning; the afternoon session, at 1:30, will be on satellites and MOONWATCH. Following the convention photograph at 3 o'clock, another IGY session on aurorae, the sun, and meteors will be held. A star party is scheduled that evening at Fuertes Observatory.

On July 5th, the 9 a.m. session will be devoted to instrumentation, followed by talks by members of the Association of Lunar and Planetary Observers. Juniors will hold their meeting at 1:30 that afternoon. The convention banquet is to start at 6:30 p.m., and after it another star party will be held.

The Northeast Region will meet on Sunday morning, July 6th, followed by a second ALPO session. The convention will close at noon.

Amateurs desiring program time should send short abstracts of their talks to G. T. Keene, 76 Westland Ave., Rochester 18, N. Y., by June 9th. None will be read in absentia or by title; reading time should be limited to 15-18 minutes.

Venus and the "old moon in the new moon's arms," seen over the Denver Civic Center, December 24, 1957.

WESTERN AMATEURS TO MEET AT PASADENA

The 10th annual convention of the Western Amateur Astronomers will be held at California Institute of Technology, Pasadena, California, on August 15-17. Cosponsors of the meeting are the Los Angeles Astronomical Society, the Excelsior Telescope Club, and the Whittier Amateur Astronomers Association.

FT. WAYNE, INDIANA

On March 5th, a group of amateurs organized the Ft. Wayne Astronomical Society. Officers elected are: Rudolph Soltesz, president; Bert Leifer, vice-president; and Paul Miller, treasurer. Interested persons and other amateur clubs are invited to communicate with the secretary, Harold Clupper, 2106 Melbourne Court, Ft. Wayne, Ind.

NORTHWEST CONVENTION

The new Oregon Museum of Science and Industry, Portland, Oregon, will be the scene for the annual meeting of the Northwest Region of the Astronomical League, July 4-6. The hosts will be the Portland Astronomical Society and the Portland Amateur Telescope Makers and Observers.

Howard Richards, Portland, has been named general chairman of the convention, while other committees are headed by: James H. Karle, program; Howard Schmadeke, exhibits; Floyd Ragner, observing; George Hohnstein, publicity; Margaret Kobs, registration; and Marge Krutsinger, social. Amateurs wishing to give talks are requested to contact Mr. Richards, at 2814 N.E. 27th Ave., Portland 12, Ore.

CHRISTMAS OVER DENVER

Harry W. Brauneis, of Aurora, Colorado, took this picture of Venus and the moon on Christmas eve, 1957. The planet is in the left center, and the lighted building in the foreground is the Denver Civic Center. Notice the earthshine on the moon, the crescent portion being overexposed. Mr. Brauneis used a $3\frac{1}{4}$-by-$4\frac{1}{4}$ Speed Graphic camera at f/4.7 in this five-second exposure on Royal Pan film.

THIS MONTH'S MEETINGS

Cleveland, Ohio: Cleveland Astronomical Society, 8 p.m., Warner and Swasey Observatory. May 16, Dr. Jurgen Stock, Case Institute of Technology, "Astronomy in South Africa."

Detroit, Mich.: Detroit Astronomical Society, 2:30 p.m., State Hall, Wayne State University. May 11, Dr. William Liller, University of Michigan, "What Comets Are Made of."

Edinburg, Tex.: Magic Valley Astronomical Society, 8 p.m., Pan American College Observatory. May 16, Paul Engle and Dr. J. L. Elliott, Pan American College, "Learning the Constellations."

Madison, Wisc.: Madison Astronomical Society, 8 p.m., Washburn Observatory. May 14, Dr. C. M. Huffer, Washburn Observatory, "The Literature of Astronomy."

New York, N. Y.: Amateur Astronomers Association, 8 p.m., American Museum of Natural History. May 21, annual business meeting.

Plainfield, N. J.: Amateur Astronomers of Union County, 8 p.m., Stillman School auditorium. May 16, motion picture, Our Mr. Sun.

Washington, D. C.: National Capital Astronomers, 8:15 p.m., Commerce Department auditorium. May 3, Dr. Geoffrey Keller, National Science Foundation, "The Results of Recent Solar Research."

A GARAGE OBSERVATORY

Last summer I designed and constructed the combination garage and observatory illustrated below. The building houses my homemade 10-inch reflector, which sits on a concrete pier 12 inches in diameter, making the mounting almost vibration-free. The floor was specially braced to carry a heavy load.

The dome is 14 feet in diameter and rotates on 30 roller-skate wheels, turning easily enough so that a mechanical drive may be added in the future. It is made entirely of waterproof plywood, since I had no equipment for working with metals.

The ribs were built up of five thicknesses of $\frac{1}{4}$-inch plywood, glued and

The Alpha-Omega Observatory, atop a garage, designed and built by Charles H. Worch, Canal Winchester, Ohio.

nailed together over a form of the proper radius. The segments between the ribs were also covered with $\frac{1}{4}$-inch plywood. The dome was completely waterproofed by covering it with muslin, then three coatings of fiberglass resin, and finally three coatings of copper-bronze boat-bottom paint.

Two pieces make up the dome slit. The top one slides back over the dome, while the bottom part, which is very light, is removed when I am observing. I estimate that the dome took 200 working hours to complete and cost about $300 in material.

It is planned to name the installation Alpha-Omega Observatory. I am a member of the Columbus Astronomical Society.

CHARLES H. WORCH
Canal Winchester, Ohio

SOUTHEAST CONVENTION

The Rocket City Astronomical Association, Huntsville, Alabama, will be the host society for the Southeast regional convention of the Astronomical League, May 10-11. Feature speakers will be Dr. Armand N. Spitz, Spitz Laboratories, and Dr. J. Allen Hynek, Smithsonian Astrophysical Observatory. The sessions are open to all interested amateurs.

Program time may be secured from Joseph Schoebert, 1074 Sunnypoint, Eau Gallie, Fla. Housing arrangements may be made with John B. Love, Box 620, Huntsville, Ala.

CRAYFORD OBSERVATORY

On the eastern edge of London, at Crayford, Kent, a new public observatory was dedicated last February. Its director is G. H. Robinson, an amateur who has been active for many years in publicizing astronomy.

The main instrument of the observatory, which was donated by Mr. Robinson, is an 18-inch reflector with optics by J. Hindle. The telescope can be used as a Cassegrainian of 525 inches focal length, a Newtonian of 72 inches focus, or a $7\frac{3}{4}$-inch off-axis Herschelian. The mirror has a 12-point flotation support.

To minimize air currents, the tube is an open framework with two-inch-square struts of beechwood. The equatorial mounting has slow motions in right ascension and declination; a motor drive and setting circles are to be added. Such accessories as a spectroscope, micrometer, and photographic equipment are also planned. Besides the 18-inch instrument, the observatory has 9- and 6-inch reflecting telescopes.

Open nights are on Fridays, when visitors may observe their favorite objects. By arrangement, classes and clubs can attend on Wednesdays and Thursdays. Individual amateurs may use the telescopes at special times.

This information is from an account of the new observatory communicated by Timothy J. Martin, 134 Brampton Rd., Bexleyheath, Kent, England.

A 9-INCH SPRINGFIELD TELESCOPE FOR PUBLIC OBSERVING

A TRIP to almost any long-established astronomical museum will show that the practice of decorating instruments is not new. As I am a band-instrument engraver by trade and have some talent in ornamental design, I accepted the challenge presented by the clean smooth surface of the tube of my 9-inch Springfield reflector. Aluminum lends itself well to engraving.

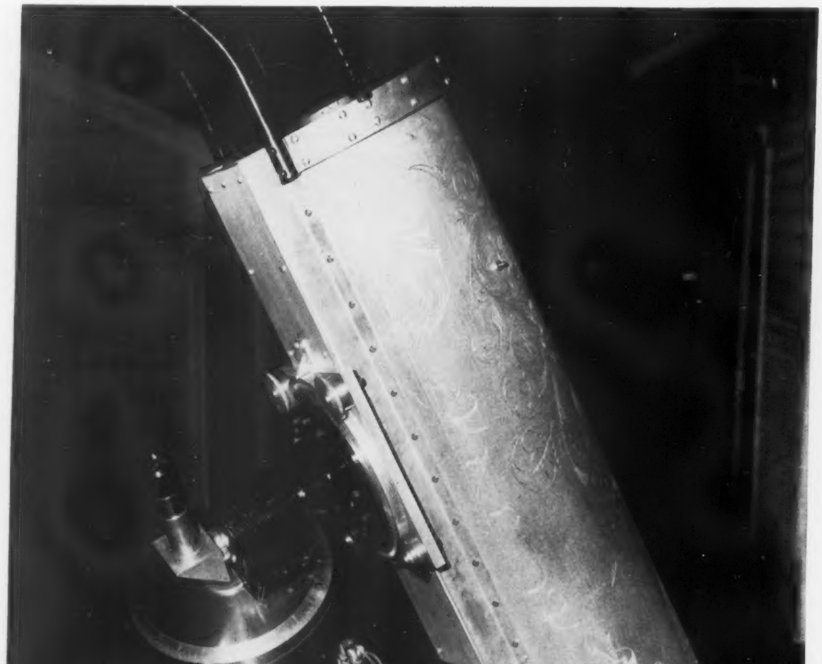
After making several preliminary sketches to lay out the design, I scoured the surface with steel wool. This produces a satin finish that adds much to the sparkle of the engraving, although it does not show too well in the photograph.

I built an oversized sawbuck in which to place the tube while engraving. On one crotch was a pair of rollers to allow easy rotation of the tube and on the other crotch a pair of rubber pads to prevent the tube from turning while the engraving was being done. The engraving process required roughly 100 to 120 hours.

A Springfield mounting was chosen since the instrument is being used for public observing. The pier is set on a triangular base that has three wheels, so that the telescope can be rolled in and out of the building on rails set securely in concrete. The complete job weighs about 300 pounds.

This project was made possible through the kindness of Robert Q. Noyes, now a chief engineer for one of our local machine-tool manufacturers.

REX M. BARTMESS
194 Gage Ave.
Elkhart, Ind.



Rex M. Bartmess built this 9-inch reflector for public observing. In this application, the Springfield type of mounting is particularly useful, as the eyepiece stays in the same place no matter where the telescope is pointed in the sky. The mounting has very precise setting circles: right ascension is on the plate below the eyepiece prism assembly, while declination is on the plate around which the saddle rotates. Counterbalance supports extend from the tube top. Only a few of the scroll designs on the decorated tube can be seen in this picture.

OBSERVER'S PAGE

Universal time is used unless otherwise noted.

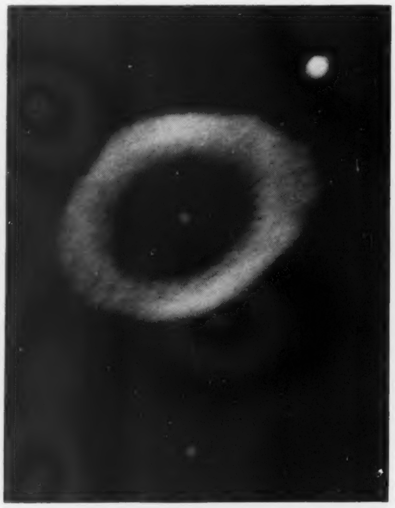
Prime-Focus Photography for the Amateur

LARGE-SCALE IMAGES are needed to give satisfactory results when photographs are made of such important celestial objects as galaxies, nebulae, planetaries, compact star clusters, and globular clusters. And for the moon and planets, the best enlargements are made from sharply focused negatives of as large a scale as possible.

Amateur-built Newtonian reflectors can be used, but the conventional diagonal mirror or prism restricts the field unduly, loses light, and may cause image deterioration. With a reflector of large enough aperture, 10 inches or better, the best place to take long-focus pictures is inside the main tube at the prime focus of the primary mirror.

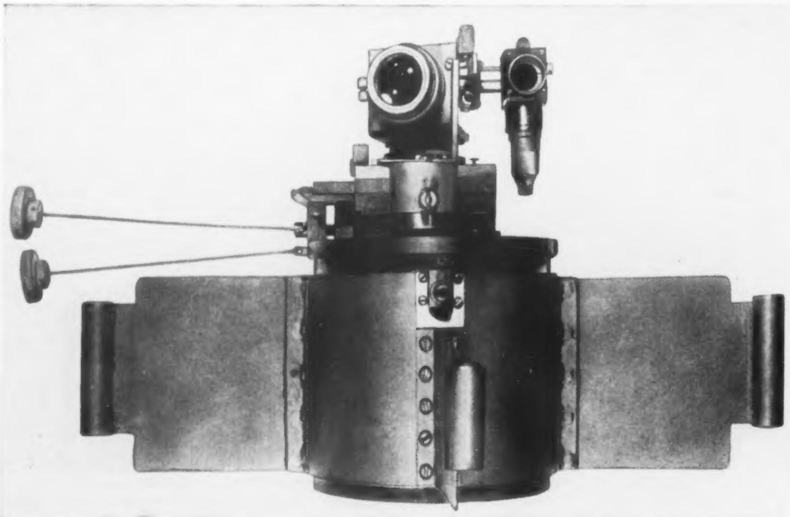
The construction of a prime-focus camera for my 12½-inch Springfield reflector was described in the Gleanings for ATM's department in January and February this year. Now I wish to outline how this camera is used. The accompanying pictures that I have obtained with it demonstrate the possibilities of this method of amateur photography. The Gleanings article should be consulted for detailed information, but for convenience the assembled camera is again pictured here. The telescope as a whole is seen on the front cover of this issue.

For first-class celestial photography, a telescope should be equipped with setting circles, a good drive, manual or electric slow-motion controls, and the optical parts must be in excellent alignment. It is of considerable importance to have the telescope mounting adjusted to point the polar axis accurately at the celestial pole. This may be done as described by Allyn J. Thompson in *Making Your Own Telescope,* page 162, by observations of Polaris.[1] The more precise this adjustment, the easier it will be to follow the guide star during the exposure.



The Ring nebula in Lyra, M57, photographed with Clarence P. Custer's prime-focus camera, enlarged 55 times from the plate scale. The exposure time was two hours, on a III-O plate, June 25, 1954.

1. A photographic method is given in Edward S. King's *A Manual of Celestial Photography,* Eastern Science Supply Co., Boston, Mass., 1931, pages 31-33.



The Custer prime-focus camera assembled for insertion in the telescope tube. The rods at the left control the plateholder movement and the shutter. The slotted screw at the top of the outer cylinder's wall is for focusing the camera. Immediately above is the field-viewing device, while suspended at the upper right are the optics used for guiding during the exposure.

The light-gathering power of the 12½-inch reflector and the value of accurate guiding are demonstrated in this 45-minute picture of M42, the Great Nebula in Orion, made by Dr. Custer January 30, 1954, on 103a-O emulsion. The nebula is larger and its structure is plainer in this photograph than in a telescope of the same aperture used visually.

An essential requirement for good pictures is the sharpest possible focus, but the position of best setting changes because of temperature and other effects beyond the observer's control. Therefore, before each exposure I focus the camera by a null test of the primary mirror, using a moderately bright star. A special backless plateholder is used, which carries a knife-edge mounted in the emulsion plane.

The process is much like the Foucault testing of a spherical mirror at the center of curvature. The Erfle eyepiece of the field-viewing device is removed as soon as the knife-edge and the star image are in close proximity. The focal adjustment is varied until the mirror darkens uniformly and simultaneously as the star image is brought behind the knife-edge with the aid of the slow-motion controls. With some care, a focus setting correct to 1/1,000 of an inch can be attained. A refinement on this method is to use two knife-edges at right angles; the difference between their settings reveals any astigmatism of the mirror. After the focus has been found, the special plateholder and the focusing control rod are removed from the assembly.

Next, the object to be photographed must be correctly centered in the camera field. If it is not bright enough to be picked up in the finder telescope, and the setting circle is not provided with a slip ring, select a nearby bright star of known right ascension and declination, centering it in the field-viewing eyepiece. The telescope is then shifted to the object's declination. A similar shift is made in right ascension by the amount of the difference between the star and the object. If the setting circle has a slip ring, it can be adjusted to indicate the star's right ascension and the telescope turned until the right ascension of the object is indicated. The latter should now appear in the field of the Erfle eyepiece, but certain nebulae may be too faint for such visual checking and the exposure must be made on the basis of the differential setting alone.

Once the plateholder is inserted, the field-viewing eyepiece can no longer be used. The device seen at the right in the picture of the assembled camera is used to find a star bright enough for accurate guiding. As explained in the February issue, pages 201 and 202, the guiding assembly inside the telescope can be shifted across and in the observer's line of sight until a suitable star is seen, and then it is locked in place with thumbscrews. The control rod is removed, to get it

A photomontage of the Great Nebula in Andromeda, M31, from three separate negatives taken by Clarence P. Custer with his 12½-inch reflector and prime-focus camera. The central section, containing the galaxy's nucleus (somewhat overexposed), was photographed after M31's meridian passage on November 7-8, 1953, from 10:30 p.m. to 1:00 a.m. Pacific standard time. The southern wing of the galaxy, at the left, was taken September 18-19, 1955, from 10:20 p.m. to 12:55 a.m., just

out of the light's path, since it does not lie in the plane of one of the spider arms.

In my telescope, it is possible to move the guiding assembly sideways for more than half an inch. This is a great help for finding suitable guide stars, for they may be few and far between! It is desirable to use a star near the optical axis of the mirror to avoid comatic flare of the image. Actually, with my f/8 mirror a guide star near the plateholder is perfectly round, and the plates show no evidence of comatic distortion, even in the corners. At the 800x magnification I use for guiding, distortion could become objectionable, but professional astronomers operate large f/5 reflectors that may have pronounced comatic distortion of the guide star.

Then I center the guide star on the cross wires of the reticle, and adjust the rheostat that controls their brightness until both wires and star can be comfortably seen. Very accurate guiding is possible if the star is so bright that the wires are visible as a dark cross on the star image. In that case, even a very slight drift of the star from the intersection can be recognized, and the star may be brought back at once with the aid of the slow motions.

These preparations of focusing and centering the subject, and locating a suitable guide star, have on occasion taken me as long as an hour or two, and sometimes the actual exposure must be postponed to the next clear night. But if the adjustments are left undisturbed, and if a chart is drawn to identify the field of the focusing eyepiece, then the guide star can be found again within a short time on the following night. For best results the exposures should be confined to the period from two hours before to two hours after the object reaches the meridian.

The next step is to close the shutter flap by means of its control rod, insert the plateholder, and withdraw the plateholder cover slide. After a final check to insure that the guide star is on the cross wires and that everything is in order, the time is noted and the shutter is opened. The exposure has begun.

For a good photograph, the observer must keep the guide star on the intersection of the cross wires, come what may. The telescope drive may have small, variable errors in rate, causing the star to drift irregularly, and requiring frequent use of the slow motions. The observer should be careful not to overshoot the mark in making corrections. If he wishes to rest during the exposure, the shutter may be closed temporarily.[2]

On my 12½-inch Springfield, the slow motions in right ascension are electrically controlled by a microswitch box with sensitive push buttons. These operate a differential motor that can increase or decrease the drive rate by about 65 per cent. After a push button has been released, the star may coast a little, but one soon learns to overcome this by momentarily pressing the button command-

2. An article about guiding, by Robert Fleischer, appeared in *Sky and Telescope*, August, 1948, page 243.

before the subject reached the meridian. The exposure was interrupted for five minutes at 10:45 when a small cloud, the only one in the sky, passed directly over the galaxy. Although the observation was made through two power lines lighted from a nearby street, they did not affect the plate. The northern end, at the right, was taken before meridian passage on October 12, 1955, from 8:55 to 11:25 p.m. The preparation of this photomontage is described on page 356.

ing motion in the opposite direction.

Good guiding requires continuous attention, and for an exposure as long as the two hours used for the Ring nebula photograph on page 352, the effort is considerable. So any means of assuring the observer's comfort is well worth while. For example, instead of holding the arm up at shoulder height for extended periods to guide manually in right ascension, it is far more convenient to use a microswitch box which can be laid on top of a ladder.

The system of shifting the whole telescope in right ascension, by means of electrically controlled slow motion, works well except near the celestial pole; there you must revert to use of the manual control rod to shift the plateholder itself. The total excursion of the plateholder in declination over an average exposure is only a few millimeters. Adjustments are necessary only at infrequent intervals.

For the very short exposures needed in lunar photography, I use a photographic shutter mounted in front of the prime-focus camera and operated by a standard cable release. With this arrangement, I can obtain the 1/100-second exposure time required for the first-quarter moon on Eastman III-O backed spectroscopic plates.

For long exposures on faint objects, a fast emulsion is essential, but do not be misled into thinking that fast press-type plates are the best for this purpose. Astronomical photography requires response to very low light intensities, for which Eastman Kodak has developed spectroscopic plates with the special "a" sensitization. When ordering, also specify antihalation backing to minimize the formation of rings around bright star images, as these are caused by light reflected from the back of the plate.[3]

Probably the Eastman 103a-O emulsion is the most satisfactory for faint objects; it is widely used by professional astronomers. Dr. Harlow Shapley has recommended the red-sensitive 103a-E emulsion for use near city lights, but my experience shows 103a-O to be superior, probably because of red sky glow from neon lights in my vicinity. As noted above, for lunar photography I employ the slower and finer-grained III-O antihalation-backed emulsion.

My prime-focus camera uses plates $2\frac{1}{3}$ by $2\frac{1}{2}$ inches, a size chosen because six of them can be cut from a single standard 5-by-7-inch plate. The field of the negatives is about $1\frac{1}{2}$ degrees square. At extra expense, Eastman Kodak will supply plates cut to any desired size, but I still use a glass cutter to cut my own in the darkroom. Inevitably the emulsion curls up along the edge, so I flatten it with a razor blade. All dust is removed from the emulsion with a camel's-hair brush before loading the plate into the holder.

The plates should be kept in sealed boxes in a refrigerator, and can be removed at any time from a few to 24 hours

3. See *Photography in Astronomy* by E. Selwyn and *Kodak Photographic Plates for Scientific and Technical Use,* both published by Eastman Kodak Co., Rochester, N. Y.

The globular cluster in Hercules, M13, photographed May 6, 1954, on 103a-O emulsion. The 1½-hour exposure was planned to terminate when the object reached the meridian; thereby Dr. Custer avoided the necessity of shifting the instrument to the other side of the pier.

before use. They are developed in D-19 and fixed in F-5. I find that development in a vertical rather than a horizontal position prevents darkening of the borders of the plate. I use a special holder to hang this size plate vertically in the developing tank.

For the photomontage of the Andromeda spiral, M31, I used Eastman 103a-O plates, each of the three sections being exposed 2½ hours and developed about 12 hours after exposure in D-19 for 5½ minutes. Dr. Walter Baade, who examined one of the original plates, commented: "The limiting magnitude of your plate is about 17.5 and I would say that about a dozen members of NGC 206 can be seen on the original plate. Since there are about 200 supergiants brighter than 17.5 scattered along the spiral arms of the Andromeda nebula, this would be roughly the number of stars in M31 which you have reached with your equipment."

The value of the original negatives of astronomical photographs can be enhanced by suitable printing. Here is my technique for the M31 montage: Each of the three plates was enlarged on 8-by-10 Medalist F-3 paper, developed in Dektol 1 to 2. The prints were copied on Panatomic-X film, developed in DK-50 to enhance the nebulosity, to increase contrast, and to darken the sky background. Again Medalist F-3 enlargements were made, but this time on double-weight paper. The two side pictures were torn irregularly to have wide, gradually thinned, beveled edges, these being pasted with rubber cement onto the central picture in correct registration. This assembly was placed under a heavy glass plate overnight to insure close adherence of the junctions, but the seams still required some retouching. Then the photomontage was recopied on Panatomic-X film. Where necessary for purposes of matching, light areas were made more opaque by rubbing small amounts of very dilute neococine into the emulsion of this film. The final enlargements were made on Medalist F-3 paper.

I have received helpful suggestions on the construction and use of this camera from Dr. N. U. Mayall, Lick Observatory, and valuable optical assistance from Arthur E. Leonard, of Davis, California. Vernon Mecum, J. R. Balkwill, Tom McCoy, and Ray Picthorn have assisted in the construction and preparation of the illustrations for this and previous articles.

CLARENCE P. CUSTER, M. D.
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Stockton, Calif.

SUNSPOT NUMBERS

The following American sunspot numbers for February were derived by Dr. Sarah J. Hill, of Whitin Observatory, Wellesley College, from AAVSO Solar Division observations.

February 1, 154; **2,** 143; **3,** 158; **4,** 159; **5,** 176; **6,** 119; **7,** 160; **8,** 131; **9,** 155; **10,** 117; **11,** 160; **12,** 143; **13,** 128; **14,** 130; **15,** 143; **16,** 162; **17,** 145; **18,** 121; **19,** 103; **20,** 156; **21,** 159; **22,** 171; **23,** 129; **24,** 156; **25,** 163; **26,** 139; **27,** 108; **28,** 85. Mean for February, 141.9.

Below are observed mean relative sunspot numbers from Zurich Observatory and its stations in Locarno and Arosa.

March 1, 109; **2,** 90; **3,** 140; **4,** 185; **5,** 203; **6,** 215; **7,** 220; **8,** 187; **9,** 177; **10,** 181; **11,** 168; **12,** 156; **13,** 145; **14,** 158; **15,** 165; **16,** 155; **17,** 164; **18,** 162; **19,** 155; **20,** 154; **21,** 156; **22,** 163; **23,** 187; **24,** 204; **25,** 180; **26,** 194; **27,** 226; **28,** 292; **29,** 302; **30,** 338; **31,** 342. Mean for March, 189.4.

Zurich numbers are transmitted by the Swiss Broadcasting Corporation on the 4th and 5th of the month. In North America these reports are heard on the 5th at 1:35 UT on wave lengths of 48.66, 31.46, and 25.28 meters, and at 4:20 UT on 31.46, 25.28, and 19.60 meters; in South America at 23:30 UT on the 4th on 31.46, 25.28, and 19.59 meters, and at 3:45 UT on the 5th on 31.46 and 25.28 meters. This schedule will be used through October 5, 1958.

URANUS IN CANCER

The star photograph above shows the planet Uranus in Cancer on March 12th at 9 p.m. Eastern standard time, photographed by Luc Secretan, Washington, D. C. South is at the top, corresponding to the view in an astronomical or inverting telescope. For this five-minute exposure, Mr. Secretan used a 6-inch Kodak anastigmat at f/4.5 and Tri-X film.

The Beehive cluster is in the center of the picture. Uranus is located three-eighths of an inch below the 4.2-magnitude star Delta Cancri, which is in the upper right corner. Gamma Cancri is at the bottom. Compare this photograph with the chart on page 207, of the February *Sky and Telescope*, which shows this year's path of the planet among the stars of the constellation Cancer.

MARCH 11TH AURORA

A brilliant red-and-white aurora occurred on the night of March 11-12. At Vankleek Hill, Ontario, Canada, Rev. J. C. Amy observed the display from 9 to 10 p.m., Eastern standard time. He reported patches of light flickering and disappearing rapidly. The most conspicuous feature was an arch across the sky from the eastern to the western horizon.

Capt. William F. Ott saw the aurora near Gloucester, Massachusetts, at 9:30 p.m. EST. He secured a beautiful color photograph one hour later.

The phenomenon was also seen by Nick Liepino at Sandwich, Illinois. A photograph that he took at 9:05 p.m. Central standard time shows a strong rayed band low in the sky. Richard R. Steck, Urbana, Illinois, also succeeded in photographing the display, as did Richard A. Phelps of Plover, Wisconsin, who during the early evening took 16 pictures of the aurora in the northern and eastern sky.

From Ft. Dodge, Iowa, Mike Larson secured the striking photograph reproduced on page 339. It shows the brilliant arc and detailed ray structure in the northeastern sky shortly after 8 p.m. CST.

DEEP-SKY WONDERS

THE first great handbook for amateur astronomers was the second volume of *A Cycle of Celestial Objects,* which Admiral W. H. Smyth published in 1844, mostly from his own observations during the preceding dozen years. This second part, also known as the *Bedford Catalogue,* has formed the basis of all subsequent English and American amateur guides. His descriptions of nebulae, clusters, and double stars are often still the most vivid available, and since he used a telescope of six inches aperture, his views compare easily with those in the average amateur telescope today.

	NGC	R.A. (1950) h m	Dec. ° ′	Mag.	Size ′ ′	Type
M49	4472	12 27.3	+ 8 16	9	4 × 4	El
M58	4579	12 35.1	+12 05	10	4 × 3	Sp
M59	4621	12 39.5	+11 55	11	3 × 2	El
M60	4649	12 41.1	+11 49	10	4 × 3	El
M61	4303	12 19.4	+ 4 45	10	6 × 6	Sp
M84	4374	12 22.6	+13 10	10	3 × 3	El
M86	4406	12 23.7	+13 13	10	4 × 3	El
M87	4486	12 28.3	+12 40	10	3 × 3	El
M89	4552	12 33.1	+12 50	11	2 × 2	El
M90	4569	12 34.3	+13 26	11	6 × 3	Sp
M104	4594	12 37.3	−11 21	8	7 × 2	Sp

There are 11 Messier galaxies within the present-day boundaries of the constellation Virgo, as listed above, and some of these attracted Smyth's particular attention. He drew the chart here, and wrote: "This is a wonderfully nebulous region, and the diffused matter occupies an extensive space, in which several of the finest objects of Messier and the Herschels will readily be picked up by the keen observer in extraordinary proximity."

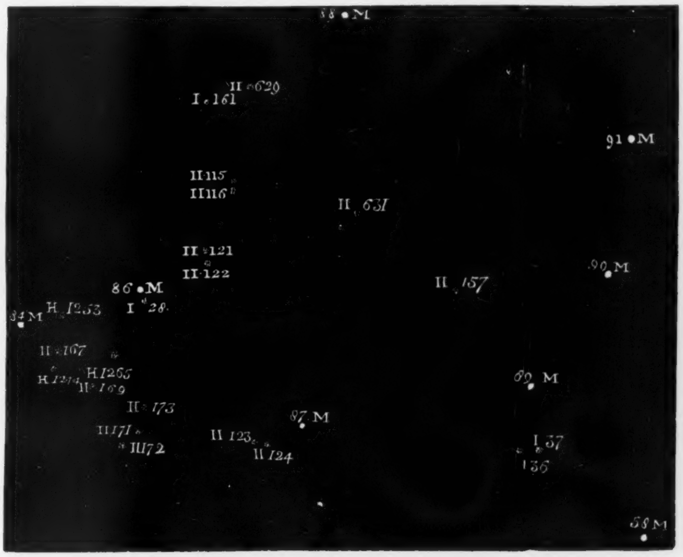
Of these galaxies, M49 was described by Messier, using a small telescope, as a "faint nebula, not seen without difficulty"; but Smyth's 6-inch refractor found it "bright, round, and well-defined . . . . has a very pearly aspect." It should be detectable without trouble in an aperture of three inches or larger.

Smyth calls M60 a double nebula, for the faint spiral NGC 4647 appears nearly to touch it. With small, bright M59 a short distance to the west, and a fainter object above, Smyth could see four galaxies in the same 93x field of view.

For M61, the admiral gives a characteristic description: "A large pale-white nebula, between the Virgin's shoulders. This is a well-defined object, but so feeble as to excite surprise that Messier detected it with his 3½-foot telescope in 1779. Under the best action of my instrument it blazes toward the middle; but in Herschel's reflector it is faintly seen to be bi-central, the nuclei 90″ apart."

The Sombrero nebula, M104, lies about 20 degrees south of these others. Its name comes from its aspect on long-exposure photographs with large reflectors.

WALTER SCOTT HOUSTON
Rte. 3, Manhattan, Kans.



Smyth's chart of a region in Virgo.

SURPLUS FILM AVAILABLE

Recently I acquired a large supply of undated surplus Eastman I-D-2 sheet film, size 4 by 5 inches. It is highly sensitive through the visual spectrum, with highest sensitivity through the green, yellow, and into the red to about 6300 angstroms. Thus it can be used effectively in bright moonlight or in city haze, if a red filter is used to cut out the blue.

This film has been used successfully to photograph a variety of celestial objects. I wish to dispose of it to serious astrophotographers, who need send only 35 cents to cover the cost of mailing each box of 25 sheets. Also, I would like a picture of each person's equipment, or of some astronomical object taken by him, to make sure the film is going to those interested in astronomy.

JOHN B. PRISER
9901 Claremont Ave., N.E.
Albuquerque, N. M.

YOU CAN TAKE IT WITH YOU

This lady is taking her observatory with her just as you might, for it only weighs a scant 11 pounds. Wherever she goes, she will be able to enjoy it, and most likely will astonish many people who think of telescopes as heavy, huge contraptions.

Did we ever tell you of this fitted case she carries? Like many other Questar parts it is the best obtainable. It is made for us in Staffordshire by British craftsmen who tailor each one by hand from the first cutting to the last neat stitch. If you know fine leather goods, you will appreciate its excellence at once. Deep ginger tan, it is lined with velvet of an old wine color, and on the door is a leather pocket for each accessory.

At left in the picture of the case below are the two front legs, and at right the adjustable one for your precise latitude, whose sliding tube and clamp screw cannot fall out to annoy you. Behind them is Questar's patented and safe sun filter, which lets you see sunspots directly at high powers in their true colors, while all the optics of the telescope remain cool and undistorted, as they should.

The extra eyepiece pouch at upper right holds the ocular you are not using, while the center pocket carries the electric cord for the synchronous motor drive. The fitted door itself, in closing, tucks in under an overhanging dust lip, which not only eliminates the need for 4 separate dust caps, but keeps dust from settling on anything inside.

Quite a package, isn't it? A complete observatory in ½ cubic foot. And how complete it is — have you ever used a rock-steady telescope with full 360° slow motions with no backlash at all? With the slipperyness of 4-inch teflon bearings aiding this smooth control, and nylon's unique property of "stickage" employed to keep the setting accurate?

The steadiness of drive is faultless. And the inclinable eyepiece, the built-in finder and power changes, offer you the most observing comfort you have ever known. We have tried hard to think of everything that would make the finest and most versatile small telescope in the world a joy to use.

On the question of the performance of the superfine small telescope we would like to submit the typical experience of Mr. M., who is president of a famous corporation, and who purchased his first Questar in July, 1954. We thought you'd like to read two letters from him in our files, which we publish with his permission:

"I expect you will remember me as one of the earlier purchasers of Questar. . . . I was a novice at astronomy at that time although experienced with many types of optical instruments.

"About a year ago I got all fired up with enthusiasm and ambition and decided that my Questar was not sufficient for my needs — I had to have something bigger and better. Consequently, I purchased a 4-inch refractor (which didn't do a thing that Questar couldn't do better and besides was a major project to set up and use), disposed of this, and now own a very good 8-inch reflector.

"My Questar had been admired by Dr. X, professor of astronomy at the college here, so in a rash moment I presented it to the school. I do not regret this because it is now being used in the best possible manner, but I miss it. After having experience with the larger instruments I now fully appreciate the importance of Questar's ease of operation. I also know that although in theory these large scopes should outperform Questar, in practice they don't always do it. In fact, I am wondering if the larger instruments are really worth it to the average amateur. In September, 1956, I had a chance to view Mars through a large observatory telescope and at the same time compare it with a 5-inch refractor. To me there was not a nickel's worth of difference, and Dr. X himself spent most of his time at the 5-inch. Of course, I realize there is no substitute for aperture when it comes to viewing and photographing the far-distant and faint objects, but as I see it there is not much useful or interesting work that an amateur can do in that field anyway."

(This letter ended with shipping instructions for another Questar, receipt of which Mr. M. acknowledged Nov. 26, 1956, saying, "The weather here is poor now . . . I have learned never to judge performance on one night's viewing.")

Later, on June 15, 1957, we received the following letter from him:

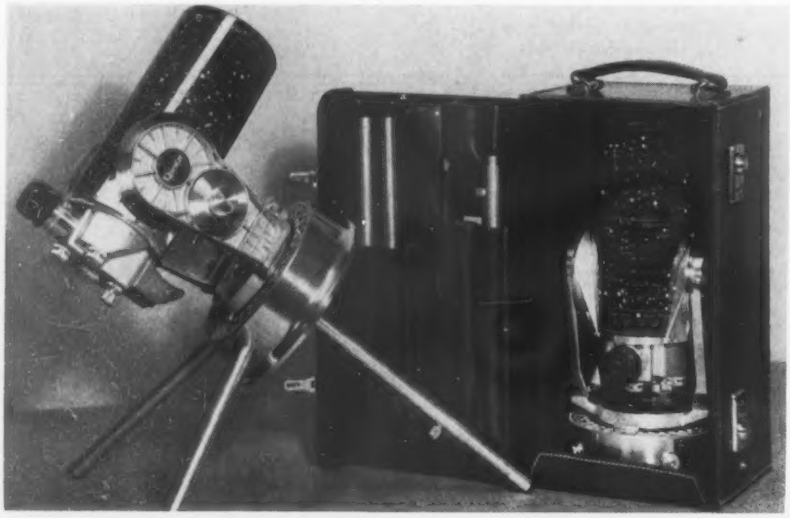
"Just a note to tell you what excellent results I obtained in observing last night. Although the moon was full, it was one of the best nights for seeing in my experience.

"At 160 power, Cassini's division in the ring of Saturn was plainly visible, as was the apparent shadow of the rings on the surface of the planet itself. Two of Jupiter's bands were quite prominent, with an occasional suggestion of a third. When I switched to my 8-inch reflector, I found that very little more detail on either of the planets could be observed.

"At approximately midnight, when Lyra was approaching the zenith, I obtained the most perfect split of the Epsilon Lyrae pairs that I have ever observed with any instrument. Although this separation of about 2 seconds is well over Questar's theoretical limit of approximately 1.3 seconds, I was most gratified, since in my experience it is most difficult ever to utilize an instrument's theoretical limit."

The list of Questar owners is a most impressive one. Men and women in all walks of life are Questar owners, and many of them are distinguished persons. The President of the United States recently presented a Questar to a visiting king. Many Questars are being used for teaching astronomy at schools, colleges, and universities, while the instrument's versatility permits it to be employed on an increasingly large number of research projects both in the field and in laboratories — in solar research, for example, and in wildlife photography and motion-picture work. Industrial users include du Pont, Corning, Electronics Corporation of America, and Sperry Gyroscope. Many government agencies besides the three armed services are Questar users.

If you have become tired of coping with the burden of large single-purpose telescopes, perhaps you would like to learn more about the world's smallest large telescope.



The De Luxe Questar complete as shown costs only $995. Extended payments if desired. Literature on request.

QUESTAR CORPORATION
New Hope, Pennsylvania

BOOKS AND THE SKY

THE STARS ABOVE US

Ernst Zinner. Charles Scribner's Sons, New York, 1957. 141 pages. $3.00.

IN THE WORDS of its preface, this little book was written "to describe the human reaction to the influences of the heavens." Its main concern is ancient mythology, the calendar, and astrology, with occasional excursions into modern astronomy. There are over 40 plates and drawings. The book originally appeared in German as *Sternglaube und Sternforschung*, and was translated into English by W. H. Johnston.

It is divided into 14 chapters. They first concern the sun, stars, moon, planets, and comets. Then there are four chapters on astrology, two sketching developments in medieval and modern astronomy that tended to discredit astrology, a chapter on unusual or erroneous ideas in modern astronomy, and finally three chapters that philosophize about the creation and evolution of the cosmos.

Dr. Zinner was, until recently, director of the Remeis Observatory in Bamberg, Germany, and has written many monographs on the history of European astronomy, but this book does not do him justice. It contains many interesting bits of star lore from Egypt, Greece, modern Europe, China, Polynesia, and other lands, but is strung together without any apparent geographical or chronological order. Some of the illustrations (such as Plate XV) do not relate to the text. The picture of the Ratisbon instrument (Plate IX) does not show it clearly. On page 6 the Egyptian king who introduced Aton worship is called Amenophis IV, but in Figs. 2 and 3 he is designated by his later-adopted name, Akhenaton. On page 45 appear references to the *Yi-King* and to the *Book of Changes* without any indication that these are the same.

There are some errors and omissions. The Chinese story of Hi and Ho is not historical. The idea that only the two planets Venus and Mercury revolve around the sun is probably not of Egyptian origin. While discussing variable stars the author speaks of Hipparchus' "star," but his quotation from Pliny mentions its motion, so it must have been a comet! The astronomical significance of Stonehenge, and Lockyer's attempt to date it, are described more fully by the archeologist R. J. C. Atkinson in the book *Stonehenge* (*Sky and Telescope*, December, 1956, page 79). Several consequences of the law of gravitation are described: the discovery of the planet Neptune, the motion of Halley's comet, and the flattening of the earth, but the law itself is mentioned only once.

The chapters on astrology contain much interesting information which would be hard to find elsewhere in one place: diagrams of a Chinese magic disk, careful description of the Petosiris disk, how astrologers changed birth dates so their horoscopes would agree with the subjects' life histories, and statistical studies that disprove astrologers' claims. Unfortunately, no clear distinction is made between two important types of ancient astrology, judicial and horoscopic, that arose in different countries and at different times (O. Neugebauer, *Publications* of the Astronomical Society of the Pacific, *58*, 39-42, 1946).

There is a long bibliography, which would be more useful if it included the author's comments on individual items and if specific references had been made to it in the text.

CHARLES GASTEYER
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Wesleyan University

HOW TO MAKE A TELESCOPE

Jean Texereau. Interscience Publishers, Inc., New York, 1957. 191 pages. $3.50.

AT LAST we have a truly logical book on telescope making, in this translation by Allen Strickler from the French. Before one has read 20 lines of this volume an appreciation of its value begins to form. The subjects of the chapters and subheads are covered fully, and the author's experience seems to bubble through the text.

The suggestion of an 8-inch mirror as the ideal size for the average amateur goes along with my own opinion. The diagrams are excellent and cover the subject as completely as the text, making a real do-it-yourself system.

Polishing the mirror face-up without fear is a great move in the right direction, hitting turned edge and pits at the same time. I recommend it. The lap-making section, however, follows Ritchey's method even to the beeswax coating. This has never proved satisfactory in our shop. Too much beeswax is bad, I feel, and smooth surfaces are more likely to come from plain pitch.

The section on testing and correcting the mirror's figure will bear intense study. All the answers are there, furnishing the means of producing a good curve. It is an advantage to know the mathematical background for determining the quality of your mirror.

The several pages on silvering are good — perhaps more amateurs should learn this fine art. We miss much of the pleasure of applied chemistry that the prewar mirror maker enjoyed when we take the easy way and have our mirrors commercially aluminized.

I question the use of the altazimuth type of mounting in preference to the equatorial, and feel that this is a soft spot in an otherwise uniformly solid work. For most astronomical observing, the

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In 1958 *Spaceflight* is being printed during January, April, July, and October; in 1959 it will be published every other month. Be sure to specify the issue with which your subscription should start. Back issues to Vol. I, No. 1, October, 1956, are available.

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SKY AND TELESCOPE BACK ISSUES

Unless otherwise specified, the previous numbers of *Sky and Telescope* to which references are made in articles and departments are available at 50 cents per copy. Since January, 1955, only the issues of January, February, October, and November, 1956, are out of print. Many issues before January, 1955, are available; write for information on particular copies.

A few bound sets of Vol. XV (November, 1955, to October, 1956) and Vol. XVI (November, 1956, to October, 1957) are available, in blue library buckram, at $12.50 each, while the supply lasts.

All items sent postpaid. Please enclose your check or money order payable to

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Harvard College Observatory Cambridge 38, Massachusetts

equatorial mounting is far more convenient.

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EDWIN F. BAILEY
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Franklin Institute
Philadelphia 3, Pa.

COSMIC VIEW
The Universe in 40 Jumps

Kees Boeke. The John Day Company, New York, 1957. 48 pages. $3.25.

IF YOU are a teacher or parent, you know how difficult it is to put across to a young mind any distinct notions of the remoteness of the stars or the minuteness of atoms. This little book by Kees Boeke, a Dutch school teacher, is an effective and attractive solution to the problem.

A journey into space is accomplished by a series of 26 illustrations of the same scene viewed from the same direction, each time at a tenfold greater distance. The first picture shows a girl seated in a school courtyard; the fourth is an aerial view in which the school building has shrunk to a tiny rectangle; by the eighth, the whole earth is visible as a globe. Successive increases in the distance of the viewing point bring the entire solar system into the 14th picture; the 19th is of the stars of the solar neighborhood; and by the last the scene is of clusters of galaxies. The sequence makes a deep impression.

A second series of 15 views extends the idea of scale into the realm of atoms and fundamental particles, again starting with the same representation of the seated girl, but with the viewer moving 10 times closer in each successive picture.

In this book's great panorama, 11 pictures cover the span from large trees to viruses. Beyond these limits, the universe would seem devoid of life. We are reminded of Eddington's remark that man is about midway in size between an atom and a star, on a geometrical scale.

Mr. Boeke has carried out his plan well. His full-page drawings are meticulously done, and the captions are simply worded yet precise. While intended for young people, the treatment is also attractive for adults. The factual accuracy is beyond reproach; one guarantee of this is that Arthur H. Compton, a Nobel prize winner in physics, consented to write the introduction.

Cosmic View should be placed in the hands of every science-minded youngster of junior high or high school age, and belongs in every school library.

MARTHA D. ASHBROOK
Weston, Mass.

THE STARS

W. Kruse and **W. Dieckvoss.** University of Michigan Press, Ann Arbor, Mich., 1957. 202 pages. $5.00.

THE OBJECTIVE of this book is primarily to present a logical, simple account of the methods of astronomical research rather than a detailed description of the universe itself. It should thus be of particular interest to the uninitiated reader.

The first part of the book, "Ways to the Stars," is a systematic approach to the problems and observational techniques of astronomical discovery. The directions, motions, and distances of the stars are first taken up, then their brightnesses, colors, temperatures, and spectra.

A general survey of the universe is presented in the second part, "The World of the Stars." Making use of the methods developed in the first section, an observational model of our galaxy is deduced from star counts, motions, and interstellar dimming and reddening. Finally, galaxies beyond our own are studied.

In general the illustrations are understandable, but often are too small and too close together. Some of the photographs do not clearly show the effect illustrated, generally because of the small scale of the reproductions. In Fig. 35, one of the two pictures of Orion is inverted, making a comparison of the red and blue images difficult.

On the whole the book is well written, except for occasional awkward explanations, which may result from incorrect translation of the original German text. One obvious case is the use of the term "o'clock" in connection with right ascension.

In spite of these relatively minor faults, this handsomely bound book is a worthwhile addition not only to the layman's library but to that of the professional teacher. The approach is extremely appealing and is worth attention by those who teach introductory astronomy.

KENNETH M. YOSS
Louisiana State University

NEW BOOKS RECEIVED

SATELLITES AND SPACEFLIGHT, *Eric Burgess*, 1957, *Macmillan*. 159 pages. $3.95.

Artificial satellites and their rockets are discussed by an active member of the British Interplanetary Society. He relates them to problems of expeditions to the moon and planets. Written for the layman, the book is fully documented with references to semitechnical papers and books from many countries of the world.

THE DAWN OF LIFE, *J. H. Rush*, 1957, *Hanover House*. 262 pages. $4.50.

The origin of life on earth, and the possibility of life on other planets are discussed here for the nontechnical reader. The author traces the evolution of man's thought on these subjects, and shows how recent progress in chemistry has cleared up much of the mystery.

THE PLANET JUPITER, *Bertrand M. Peek*, 1958, *Macmillan*. 283 pages. $8.50.

A former director of the Jupiter section of the British Astronomical Association has analyzed the great accumulation of visual observations of this planet. The rotation periods of various individual features permit a detailed picture of circulation patterns in the Jovian atmosphere to be drawn. There are many observing suggestions for amateurs.

TECHNOLOGIE DER ASTRONOMISCHEN OPTIK, *D. D. Maksutow*, 1954, *VEB Verlag Technik*, Oranienburger Strasse 13-14, Berlin C 2, East Germany. 251 pages. DM 29.

The inventor of the Maksutov-type telescope originally prepared this monograph in Russian. The present German translation was published in 1954, but was not widely publicized in the United States. In it Maksutov discusses in detail the theory and practice of making and testing mirrors, devoting two chapters to the testing of lenses and aspheric surfaces. This book is intended for both professional and amateur optical workers, who will find it of great value.

EXPLORING THE DISTANT STARS, *Clyde B. Clason*, 1958, *Putnam's*. 384 pages. $5.00.

In a colorful, informal style, the subject of stellar astronomy is discussed for the beginner. There are 60 pages devoted to galaxies.

SOLAR-TERRESTRISCHE BEZIEHUNGEN IN METEOROLOGIE UND BIOLOGIE, *Hellmut Berg*, 1957, *Akademische Verlagsgesellschaft*, Sternwartenstrasse 8, Leipzig C 1, East Germany. 172 pages. DM 23.

Solar-terrestrial relationships in meteorology and biology are reviewed in this monograph, in German, by a professor of meteorology and geophysics. There is an extended account of many attempts to trace some connection between solar changes and weather, or correlations between the sun's activity and vital statistics. The bibliography lists 199 books and articles.

THE PRESENT AND FUTURE OF THE TELESCOPE OF MODERATE SIZE, *Frank Bradshaw Wood*, editor, 1958, *University of Pennsylvania Press*. 219 pages. $5.00.

The widening usefulness of telescopes from 12 to 40 inches in aperture is discussed in these 14 papers from a symposium in 1956. New horizons are being opened by such electronic developments as the image converter. The future of classical techniques, including photographic astrometry, is also explored.

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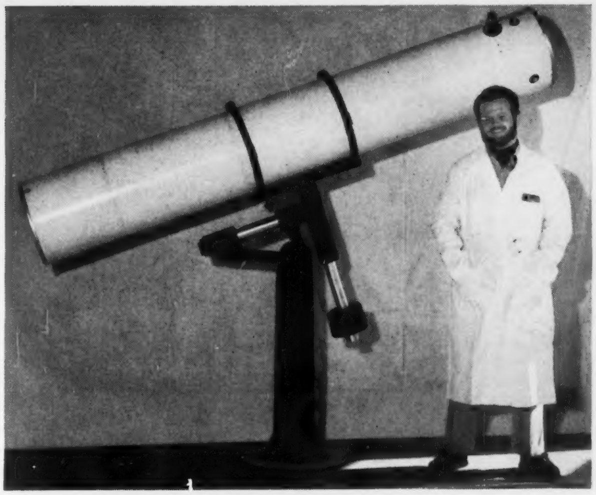

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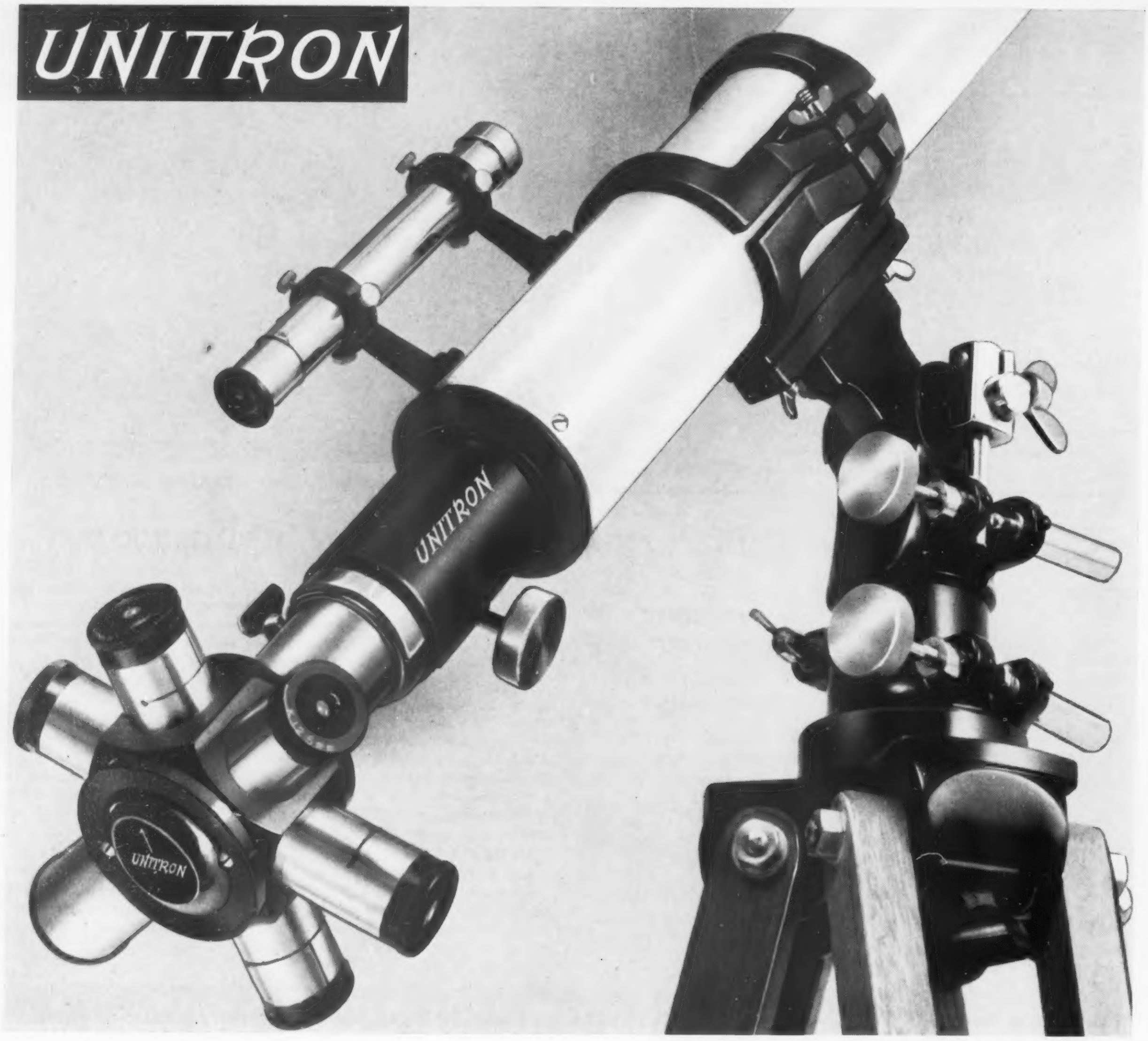

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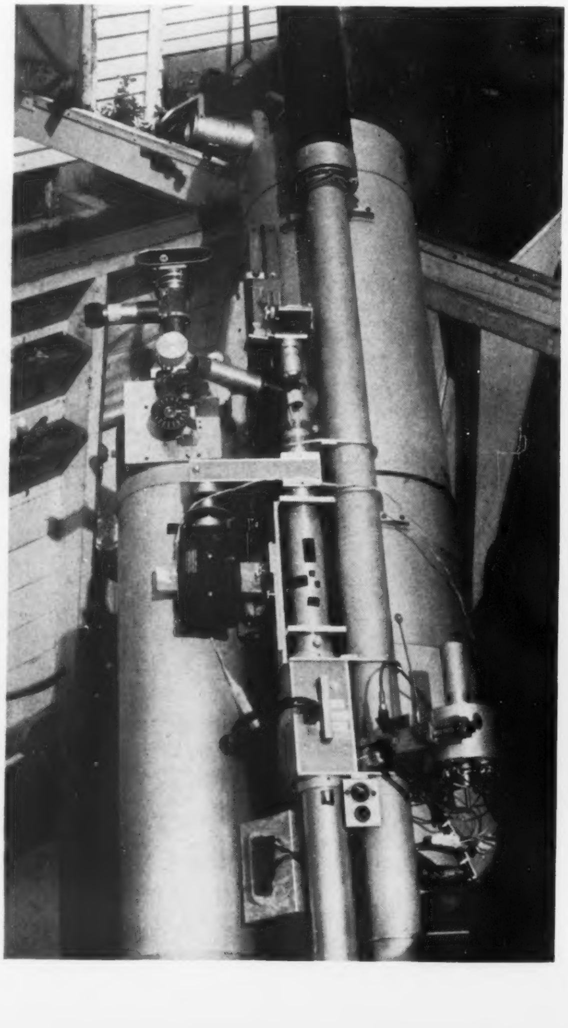
Construction of a Solar Telescope

PROMINENCES extending thousands of miles from the edge of the sun, solar flares, spicules, and geyserlike surges of brilliant material rising vertically from the chromosphere, are some of the fascinating phenomena awaiting the amateur who builds a coronagraph-type telescope for solar observing.

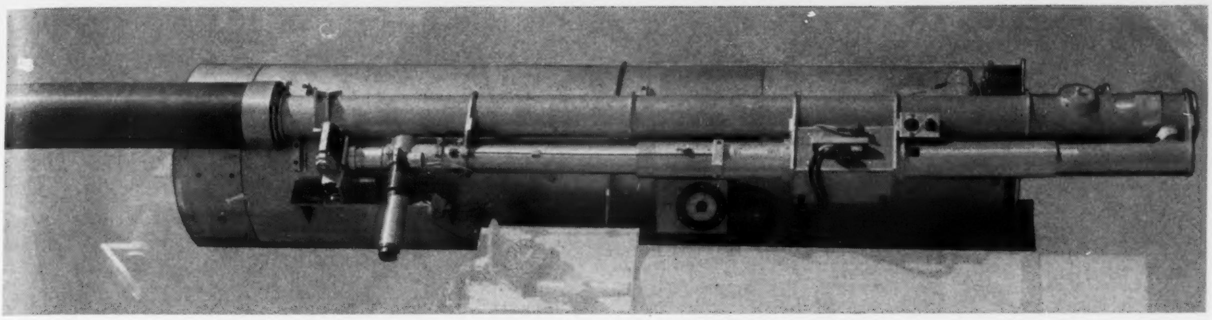
In my case, the seeing in the Buffalo, New York, area had become so bad that I could no longer photograph stars or observe the night sky. As I have machine-shop experience, I accepted the challenge of building the specialized equipment necessary for direct observations of the sun's chromosphere and prominences. The photographs shown with this article are but a few of the thousands I have secured with my solar telescope.

This instrument is one of several I use for observing the sun; they are seen together in the accompanying picture. The largest tube, on which the solar telescope is mounted, is part of another optical system. It contains a 12½-inch f/5 paraboloidal mirror that feeds sunlight into the optical train of an Ebert-type spectrograph. The latter has an 8-inch mirror within the smaller tube at the left in the picture. Near the top of this spectrograph tube is a replica grating, its orientation controlled by the calibrated dial. Details of this spectrographic equipment can be found in *Scientific American,* September, 1956, page 259, while the conversion of the apparatus to a spectroheliograph is described in that same magazine for April, 1958, page 126. Only the solar telescope will be discussed here.

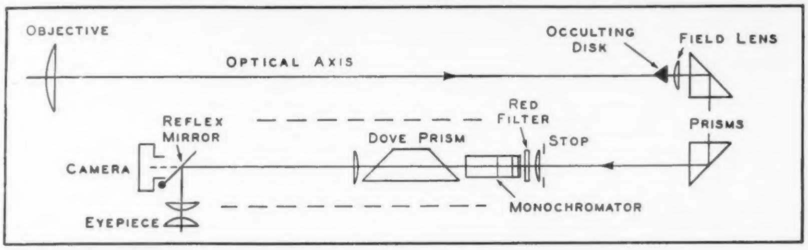
The solar telescope's 4¼-inch objective is carried in the black tube that extends out of the top of the picture of the instruments as a whole, and which is at the left in the closeup on the facing page. Because of lack of room in my observatory, it has been necessary to jackknife the ray path by means of two prisms at the other end of the system, as shown in the diagram of the parts opposite. The square section in the lower part of the second tube contains the quartz polarizing monochromator. The heavy electrical cables



Walter Semerau's elaborate equipment for observing and photographing phenomena on the sun is constantly being changed and improved. Two 35-mm. cameras are now used, one on the solar telescope described in this article; this telescope is contained in the two long, narrow tubes that are central in the picture. The other camera, in the upper left, is mounted behind an Anderson rotating-prism assembly used for making spectrograms of the solar disk. The short barrel-like device at the lower right houses an automatic photoelectric guider that is under development.



Compare the parts of the prominence telescope with the diagram below. Also seen is the large tube of the 12½-inch reflector on which the apparatus is mounted, but other parts of Mr. Semerau's equipment have been masked out.



lead to a sensitive microvoltmeter for keeping track of temperature changes.

Toward the left in the assembly is an eyepiece for visual observing, while above it is mounted a single-lens reflex camera, used without its lens, for making black-and-white and color pictures of events on the sun.

Objective lens. As the observations will be made in nearly monochromatic light (usually hydrogen alpha at 6563 angstroms), the objective lens need not be achromatic. Furthermore, to reduce light scattering, a simple plano-convex lens of very long focus is desirable, f/21 in my case. The spherical aberration of such a long-focus lens can be ignored (but may be removed according to the instructions by E. Pettit in *Amateur Telescope Making — Book Three,* page 422).

The lens surfaces must have as perfect a finish as possible. Dust, polishing scratches (sleeks), internal bubbles, and striae, all scatter light, thereby reducing contrast and hiding fine details in the image. The other optical elements in the unit must likewise have superfine surfaces. War-surplus or commercial optics may need lap polishing for short spells to obtain the quality of polish required.

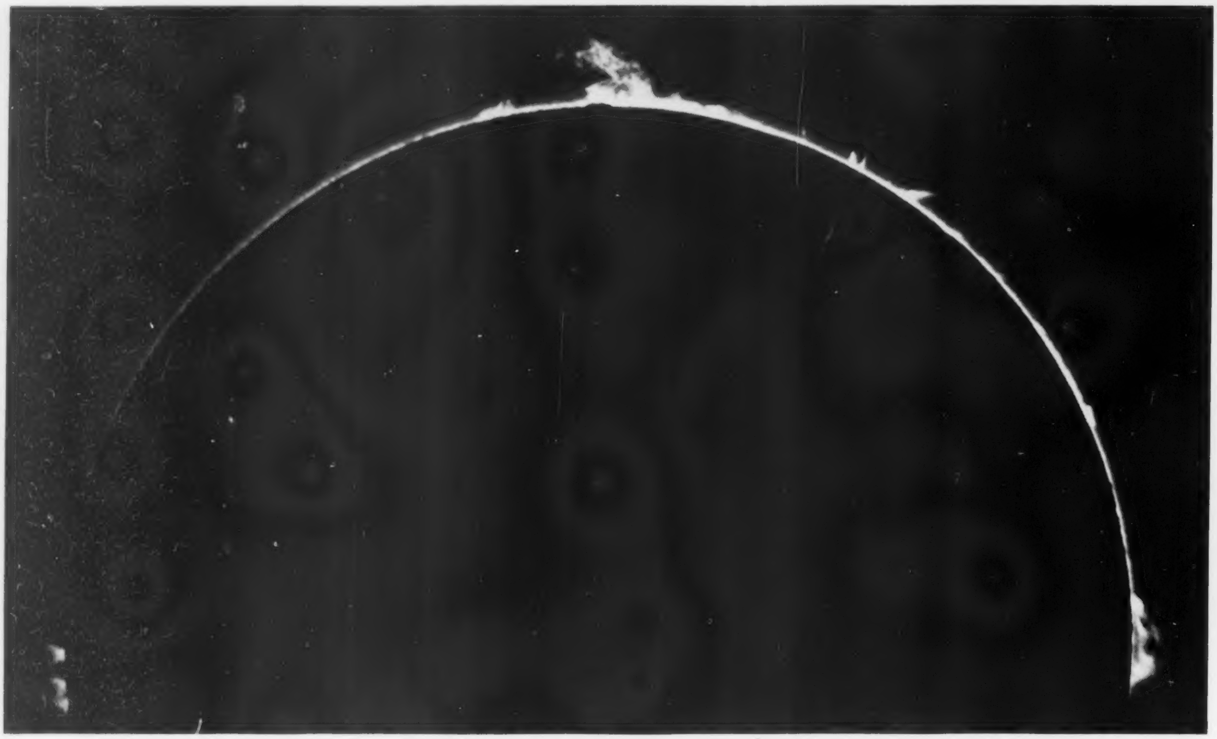
Occulting disk. The design of this very important part of the solar telescope needs considerable thought. It must rotate about the optical axis. This may be accomplished with a ring gear having an inside diameter larger than the field covered by the telescope. Since the viewing field I get is larger than the picture area on 35-mm. film, by rotating the pinion and gear I can orient the occulting-disk supporting arm so it is not visible in the picture.

For best results, it should be possible to place the occulting disk's edge anywhere in the field of view. Visual observing is better at the center of the field, so when prominences on the sun's limb are viewed there, the occulting-disk edge must be near the optical axis. On the other hand, more of the sun's limb can be photographed in one picture if the center of the disk is near the optical axis.

The occulting disk is placed just in front of and very close to the focal plane of the objective lens. It is, in principle, cone-shaped to scatter sunlight properly, but may be made a beveled disk as drawn on the next page. If the edge were not beveled but square-cut, grazingly reflected light from the limb of the sun might be scattered into the optical system. The beveled edge should be sharp and burr-free; great care should be taken to avoid nicking it.

Since the diameter of the sun's image

On October 5, 1956, after three morning hours of uneventful prominence photography, Mr. Semerau returned from lunch to find a very active prominence erupting from the sun. At 1:10 p.m., the time of this picture, the total length of the prominence was about 250,000 miles.

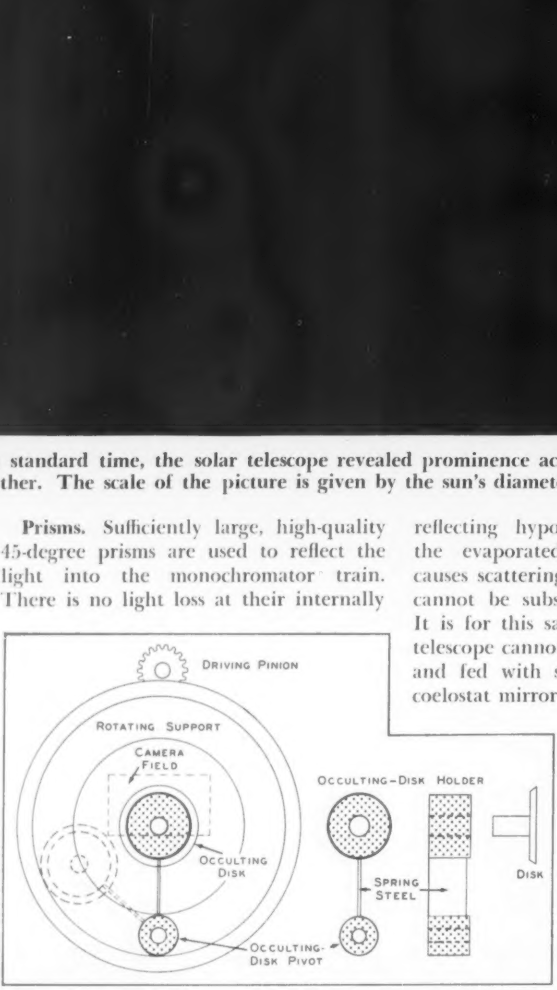


On June 26, 1956, at 11:42 a.m. Eastern standard time, the solar telescope revealed prominence activity at points on the sun's limb about 90 degrees from each other. The scale of the picture is given by the sun's diameter, some 864,000 miles.

changes during the year, the same occulting disk cannot be used for more than two or three months, after which it will be either too large or too small. I have several disks, differing in steps of 0.005″ diameter, and for each observation choose one that is very slightly smaller than the image of the sun.

Field lens. This is located just behind the occulting disk, very close to but not in the focal plane of the objective. If it were in the focal plane, any dust on the lens would be in sharp focus at the eyepiece or camera. The field lens is chosen to form an image of the objective at the diaphragm or stop farther along in the optical system. Although some monochromator designs do not include this field lens, it improves the performance of the instrument when used with the stop.

Prisms. Sufficiently large, high-quality 45-degree prisms are used to reflect the light into the monochromator train. There is no light loss at their internally reflecting hypotenuse surfaces. Because the evaporated coating on a mirror causes scattering of light, mirror surfaces cannot be substituted for these prisms. It is for this same reason that the solar telescope cannot be mounted horizontally and fed with sunlight reflected from a coelostat mirror.



One of the most important parts of the solar telescope is the occulting-disk assembly. The spring-steel supporting arm can be rotated out of the observing area.

Stop or diaphragm. This is a disk with a central hole very slightly smaller in diameter than the image formed by the field lens. It combines with the latter to reduce measurably the edge diffraction from the objective, thereby avoiding another possible source of scattered light.

Collimator. This lens is placed immediately behind (left of) the stop, and its focal length is equal to its distance from the focal plane of the front objective lens. My collimator has a focal length of $22\frac{1}{2}''$ and sends a parallel beam of light through the monochromator assembly.

Filter. For hydrogen-alpha light, a Corning 2408 red glass filter helps to isolate that spectral region. Placed between the collimating lens and the monochroma-

On September 1, 1957, between 13[h] and 19[h], prominence activity was higher than normal. Great hydrogen clouds extended some 45 degrees around the sun's edge.

tor, it absorbs practically all wave lengths of the solar spectrum except a band about 600 angstroms wide.

Monochromator. This is the heart of the solar telescope, and consists of a series of seven high-quality crystal-quartz blocks of specified thicknesses, with a sheet of polaroid film sandwiched between each two blocks. The optical axes of the quartz are carefully aligned in one direction, and the polaroid axes are set at exactly 45 degrees to that direction.

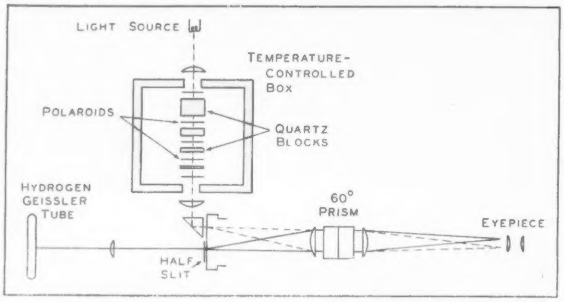
The purpose of the monochromator is to filter out all unwanted wave lengths except that of the hydrogen-alpha line. The bandpass of my monochromator at present is four angstroms. There are actually a few more transmitted frequencies in nearby regions of the spectrum, but these can be eliminated by appropriate filters behind the monochromator.

Construction of a monochromator is a demanding task, which has been described in an article by R. B. Dunn in *Sky and Telescope*,[1] and by Henry E. Paul in *Amateur Telescope Making — Book Three*, page 376, where a further bibliography on the subject may be found.

When a monochromator is installed in the solar telescope, the thinnest quartz block should face toward the sun, on the assumption that thin elements are least affected by temperature changes and that there are more pieces of polaroid to absorb the heat. For work in the red region of the spectrum, polaroid film HN 38-40 should be used.

Both Mr. Dunn and Dr. Paul give detailed instructions on setting up a suitable light source and breadboard spectrometer for optically testing the thickness of each quartz block and checking the passbands of a combination of blocks. It is quite difficult to test for errors in the complete seven-block assembly, due to the great loss of light through the polaroid filters. Small errors may remain unnoticed unless the light source is very powerful.

1. Available as a reprint for 50 cents from Sky Publishing Corporation, Harvard Observatory, Cambridge 38, Mass.



This workshop setup for checking the very narrow bandpass of the completed monochromator permits detection of smaller errors than do other testing methods. Only a few of the monochromator elements are shown.

But such bright illumination is not essential if the slit recommended by these other workers is removed and all the light that passes through the blocks is allowed to enter the spectrometer. Each passband then forms a monochromatic image of the light source, rendering very small errors detectable at the spectrometer eyepiece.

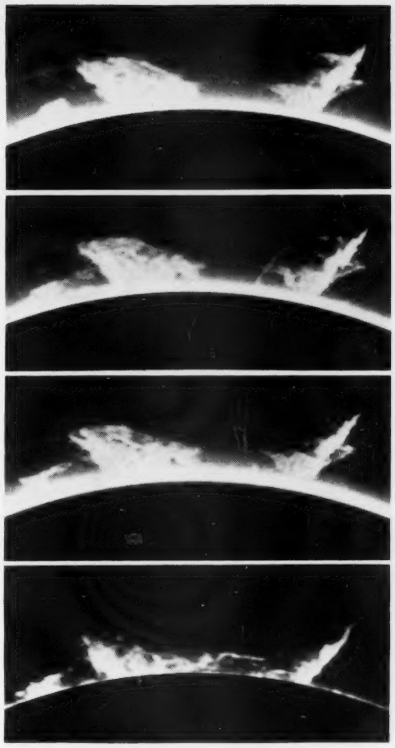
A reference spectrum from the hydrogen Geissler tube is included, as shown in the drawing, by having the bottom half of the spectrometer entrance face covered by a slit. A right-angle prism sends the monochromator light through the upper half of the spectrometer.

Dove prism. This is not a necessary item, but it is useful for rotating the final image of the desired part of the sun when composing a picture. It is driven by a ring gear and pinion fastened to a rod that can easily be reached by the observer. This rod, in the pictures of the instrument, extends along the upper side of the thinner tube from near the eyepiece to just above the microvoltmeter.

Camera and eyepiece. The second collimating lens must be of the same size and focal length as the first one ($22\frac{1}{2}''$ in my instrument), in order to form the sun's monochromatic image in the final focal plane. The image can be studied by an eyepiece or photographed with a camera. The special reflex mirror that I have placed in front of the camera opening allows me to view the image of a prominence until just before an exposure is made. The reflex mirror and camera shutter operate electrically by means of solenoids.

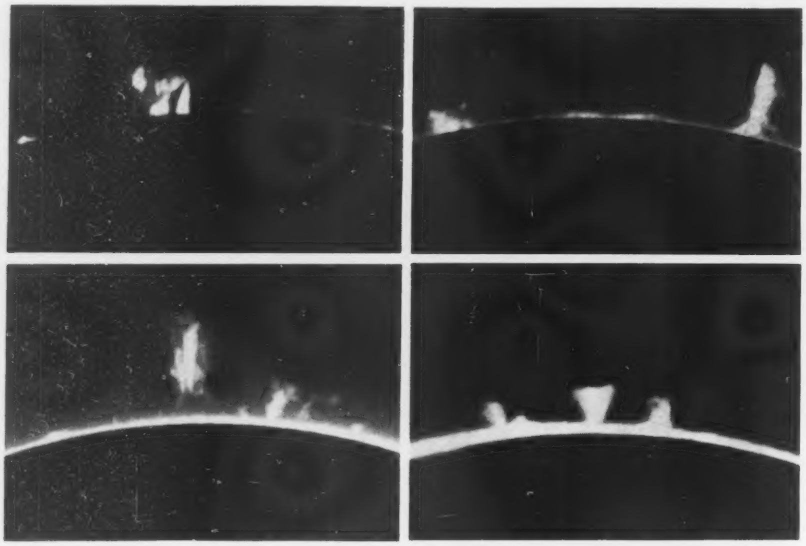
Support. When I first built my solar telescope, I thought it should be encased in a lighttight dustfree enclosure. In spite of hours of painstaking machine work and careful fitting of parts, dust and moisture worked their way inside due to the pumping action of the air within, expanding and contracting with temperature changes.

The monochromator is heated to an operating temperature of 104 degrees Fahrenheit (40° C.). But I found that as



Changes in the prominences of September 28, 1956, are recorded in this series, taken (top to bottom) at 12:09 p.m. Eastern standard time, 12:21, 12:34, and 1:56. In the large prominence at the right, a graceful arc of descending matter is most intense in the second picture from the top.

The sliding-roof construction of Mr. Semerau's observatory facilitates putting his equipment into operation quickly when outbursts of solar activity occur. All his apparatus is carried on one equatorial mounting.



Prominences of many different shapes are recorded with the solar camera. At the upper left is Mr. Semerau's "shaggy dog" prominence.

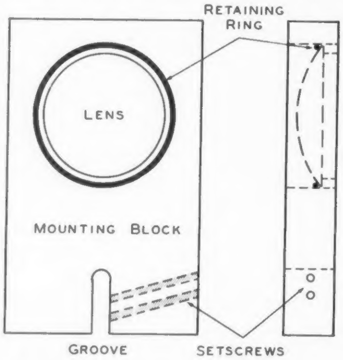
it cooled down after observing, the air inside contracted and drew in moist dust-laden air. In below-freezing situations, it is obvious that moisture condenses on all the optics; to evaporate this internal moisture the monochromator heat control has to be turned on about two hours before observing begins again.

The open type of tube construction, first mentioned to me by Dr. Paul (who is a Norwich, New York, amateur), is used at the large solar observatories, such as Sacramento Peak Observatory (*Sky and Telescope,* August, 1956, page 436). Some of the bothersome breathing effect would be eliminated; also, it is easier to build, to clean the optics, to detect misalignment of the elements. Such a supporting frame would be less expensive, and there would be more freedom to change and rearrange the elements.

It would, of course, still be necessary to house the monochromator parts in a temperature-controlled box. Also suggested is a light-baffle tube extending from the monochromator to the eyepiece, as shown by the dashed lines in the diagram on page 369.

Dr. Paul's idea was to use two rigid parallel ways that could serve as optical benches on which to clamp all components. A 6″ or 8″ aluminum channel $\frac{1}{4}$″ thick or an I-beam might do as a rigid support. To allow for future changes, choose a base support 6″ to 8″ longer than the focal length of the primary objective lens, if the folded design described here is adopted.

For simplicity, all lens mounts could be alike, a suitable type being illustrated here. Each should have the same groove



Where the lenses of a solar telescope are not mounted in a closed tube, the supporting elements can be simple in design, as shown by this diagram.

on the vertical center line to fit the bed of the instrument support. All the optical elements must be centered the same distance above the support. If mechanical stopblocks are clamped at each mounting form, it is easy to change cameras, secondary lenses, occulting disks, and other components on this open type of construction.

All the work is worth the effort. Looking at the ever-changing solar prominences and their unexpected outbursts is like watching a continuous color television show without the commercials.

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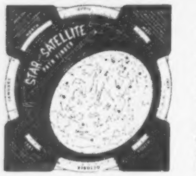

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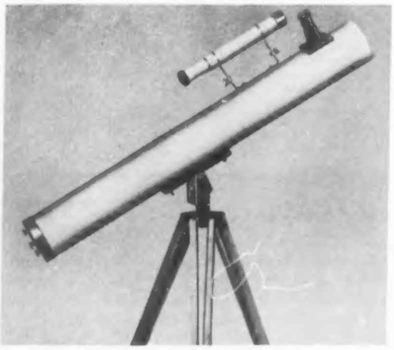

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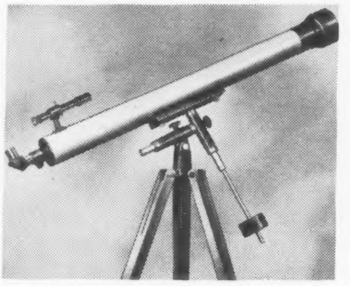

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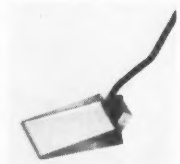
There are several methods of reducing intensity of the sun's rays, but the most popular is using a Herschel wedge plus a sun filter over the eyepiece.

UNMOUNTED HERSCHEL WEDGE

Size, 40 mm. x 55 mm.; wedge angle is 10°. The critical surface is flat to ¼ wave. Not mounted.

Stock #30,265-Y...$3.50

MOUNTED HERSCHEL WEDGE



Same size as above but mounted with diagonal holder for reflectors. Fits our rack-and-pinion holder, Stock No. 50,077-Y, that is also used on our 4¼" and 6" reflectors. Holder rod is long enough for 4¼", 6", and 8" mirrors. Rod is 5/32" O.D. and 5" long.

Stock #30,266-Y....$5.50

SUN FILTERS

These filters help protect the eyes from normal visible rays, invisible infrared, and ultraviolet. 3-mm. thickness. Per cent of light transmission: visible 0.0091%, ultraviolet none, infrared 0.0190%.

Stock No.	Size	Price
2726-Y	1" x 1"	$1.00
2727-Y	2" x 2"	2.00
2728-Y	⅞" (round)	1.25
2729-Y	1¼" (round)	1.50

WAR-SURPLUS TELESCOPE EYEPIECE

Mounted Kellner Eyepiece, Type 3. 2 achromats, f.l. 28 mm., eye relief 22 mm. An extension added, O.D. 1¼", standard for most types of telescopes. Gov't. cost $26.50.

Stock #5223-Y......$7.95 ppd.

EDSCORP SATELLITE TELESCOPE

OPTICS: The Satellite Scope has two important optical characteristics: A wide (51-mm.) diameter, low-reflection-coated objective lens. A six-element extremely wide-field, coated Erfle eyepiece that, in combination with the objective, gives 5.5 power with a big 12° field and over 7-mm. exit pupil.

OTHER USES FOR THE SATELLITE SCOPE

1. Makes a perfect wide-field finder. A special groove on the barrel helps in locating it in the finder mount. Fits our twin-ring finder mount, Stock No. 70,079-Y—$9.95. 2. Use the Erfle eyepiece on your regular astronomical telescope. You will need our adapter, Stock No. 30,171-Y—$3.95, which gives you an O.D. of 1¼". This eyepiece cost the government $56.00! 3. Makes a wonderful comet seeker; see complete asterisms. 4. Makes a fine rich-field telescope; see wide areas of sky with deep penetration.

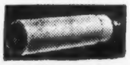
Especially Made for Members of MOONWATCH

Stock #70,074-Y...................................$49.50 ppd.

Now — See the Satellites

NEW, LOW-PRICE "SATELLITER" TELESCOPE

First Time — Only $9.95 ppd.



Get ready for the sky show as more satellites are vaulted into space. Our new, low-price "Satelliter" telescope may also be used to view comets and as a rich-field scope for viewing star clusters. 5 power, wide 12° field, slight distortion at outer edges because of unusually wide field. Use of high-quality war-surplus optics makes possible this bargain. Full 2" achromatic objective — large 9-mm. exit pupil for night use. Scope is 10" long, weighs less than one pound.

Stock #70,150-Y....................................$9.95 ppd.

WAR-SURPLUS "SATELLITER" MOUNT

We have just discovered a radar tube mount (Gov't. cost about $50.00) that is very much like our mount for the regular MOONWATCH telescope. We include a spacer so that our $9.95 "Satelliter" telescope will fit the tube. You can attach a mirror on the end or purchase the model to which we have attached a 2" x 3" first-surface mirror with a metal bracket. The scope holder is mounted on a removable 4"-long T-slot slide, and the adjustable base has one 12" long.

The pivot point of the mirror holder will be about 1¾" below the optical axis of the mirror. This does not allow its easy use at an official MOONWATCH station. However, it is a minor point for other groups or for satellite viewing by an individual.

Adjustable through about 75° angle. Tube has spring-shock mounting. Also can be mounted and used vertically. Made of light-weight aluminum and magnesium.

Stock #70,151-Y....Mount only...........$6.00 ppd.
Stock #70,152-Y....Mount with mirror and bracket (as illustrated)................$9.00 ppd.
Stock #70,153-Y....Complete with mirror and $9.95 "Satelliter" telescope..........$18.95 ppd.

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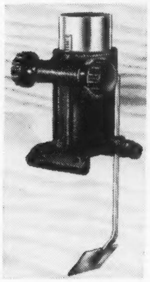
BUILD A SOLAR-ENERGY FURNACE

Great Project for Geophysical Year!

A fascinating new field. You can build your own solar furnace for experimentation — many practical uses. It's easy, inexpensive — use your scrap wood. We furnish instruction booklet. This sun-powered furnace will generate terrific heat — 2000° to 3000°. Fuses enamel to metal. Produces many unusual fusing effects. Sets paper aflame in seconds. Use our Fresnel lens — 14¾" diameter, f.l. 14".

Stock #70,130-Y....Package of 1........$6.00 ppd.
Stock #70,131-Y....Package of 2........11.00 ppd.
Stock #70,132-Y....Package of 4........20.00 ppd.

Rack & Pinion Eyepiece Mounts



For Reflectors

For Refractors

Now you can improve performance in a most important part of your telescope — the eyepiece holder. Smooth, trouble-free focusing will help you to get professional performance. Look at all these fine features: real rack-and-pinion focusing with variable tension adjustment; tube accommodates standard 1¼" eyepieces and accessory equipment; lightweight aluminum body casting; focusing tube and rack of chrome-plated brass; body finished in black wrinkle paint. No. 50,077-Y is for reflecting telescopes, has focus travel of over 2", and is made to fit any diameter or type tubing by attaching through small holes in the base. Nos. 50,103-Y and 50,108-Y are for refractors and have focus travel of over 4". Will fit our 2⅞" I.D. and our 3⅞" I.D. aluminum tubes respectively.

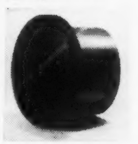
Stock #50,077-Y (less diagonal holder) $9.95 ppd.
Stock #60,035-Y (diagonal holder only) 1.00 ppd.
Stock #50,103-Y (for 2⅞" I.D. tubing) 12.95 ppd.
Stock #50,108-Y (for 3⅞" I.D. tubing) 13.95 ppd.

7X FINDER TELESCOPE–ACHROMATIC

Stock #50,080-Y Finder alone, less ring mounts...$9.95
Stock #50,075-Y Ring mounts per pair..........$3.95

Mounted Ramsden Eyepieces

Standard 1¼" Diameter



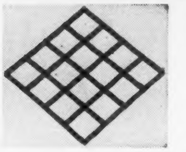
Our economy model, standard-size (1¼" O.D.) eyepiece. We mounted two excellent quality plano-convex lenses in black anodized aluminum barrels instead of chrome-plated brass to save you money. The clear image you get with these will surprise you. Directions for using short focal length eyepieces are included with both the ¼" and ½" models.

Stock #30,204-Y....¼" focal length....$4.75 ppd.
Stock #30,203-Y....½" focal length....$4.50 ppd.

YOUR ORDER WILL BE SHIPPED PROMPTLY — WITHIN 24 HOURS!

RUBBER PITCH-LAP MAT

Saves Mirror Makers Time and Trouble

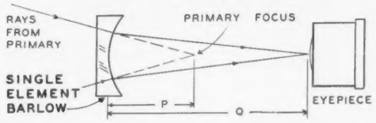


A rubber pitch-lap mat is used for forming the pitch-lap channels. Just pour the melted pitch on the tool, lay the mat on top and then press it in with your mirror to form the channels. When the pitch sets, an easy pull will remove the mat. In minutes instead of hours you are ready to polish. Eliminates time-consuming and tedious hand-cutting of the channels of the pitch lap.

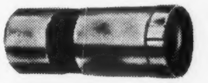
All those disappointing break outs of the pitch, common when hand-cutting the channels, are avoided. You no longer have to pour and cut two or three laps before getting a usable one. With our Rubber Pitch-Lap Mat you can use the first one you make.

Stock No.	Size	For Mirror Diam.	Price ppd.
50,171-Y	**13½" x 13½"**	**8", 10", 12"**	**$2.00**
60,061-Y	**6" x 6"**	**4¼", 6"**	**1.00**

DOUBLE AND TRIPLE YOUR TELESCOPE'S POWER WITH A BARLOW LENS



WHAT IS A BARLOW? A Barlow lens is a negative lens used to increase the power of a telescope without resorting to short focal length eyepieces, and without the need for long, cumbersome telescope tubes. Referring to the diagram above, a Barlow is placed the distance P inside the primary focus of the mirror or objective. The Barlow diverges the beam to a distance Q. This focus is observed with the eyepiece in the usual manner. Thus, a Barlow may be mounted in the same tube that holds the eyepiece, making it very easy to achieve the extra power. The new power of the telescope is not, as you might suppose, due to the extra focal length given the objective by the difference between P and Q. It is defined as the original power of the telescope times the quotient of P divided into Q.



Beautiful chrome mount. We now have our Barlow lens mounted in chrome-plated brass tubing with special spacer rings that enable you to vary easily the power by sliding split rings out one end and placing them in other end. Comes to you ready to use. Just slide our mounted lens into your 1¼" I.D. tubing, then slide your 1¼" O.D. eyepieces into our chrome-plated tubing. Two pieces provided, one for regular focal length eyepieces and one for short focal length ones.

Remember, in addition to doubling and tripling your power, a Barlow lens increases your eye relief and makes using a short focal length eyepiece easier.

Don't fail to try one of these. Many people do not realize the many advantages of a Barlow and the much greater use they can get from their telescopes. Our Barlow has a focal length of −1-5/16". We have received many complimentary letters about this lens. So sure are we that you will like it that we sell it under a 30-day guarantee of satisfaction or your full purchase price returned — no questions asked. You can't lose, so order today.

Stock #30,200-Y Mounted Barlow lens......$8.00 ppd.

BRASS TUBING

2 pieces, 3" long, slide fitting. Blackened brass. I.D. 1-3/16", O.D. 1-5/16".

Stock #40,165-Y........................$1.75 ppd.

30-day Money Back Guarantee as with all our Merchandise!

OPTICAL IDEA & GADGET CONTEST

In celebration of International Geophysical Year—

Contest Ends Dec. 31, 1958

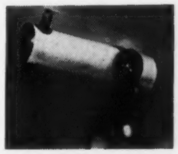
Our Catalog has full details on rules, prizes and entry blank — Write for Catalog "Y."

PRISM STAR DIAGONAL

For comfortable viewing of the stars near the zenith or high overhead with refracting telescopes using standard size (1¼" O.D.) eyepieces, or you can make an adapter for substandard refractors. Contains an excellent quality aluminized right-angle prism. Tubes are satin chrome-plated brass. Body is black wrinkle cast aluminum. Optical path of the system is about 3½".

Stock #70,077-Y..............................$12.00 ppd.

SPITZ MOONSCOPE



A precision-made 32-power reflecting telescope — by makers of Spitz Jr. Planetarium. Clearly reveals the craters of the moon, shows moons of Jupiter, other wonders of the heavens. Based on same principles as world's giant telescopes. Stands 36" high on removable legs. Adjustable 3" polished and corrected mirror. Fork-type altazimuth mount rotates on full 360° circle — swings to any location in the sky. Fascinating 18-page instruction book, sturdy carrying case.

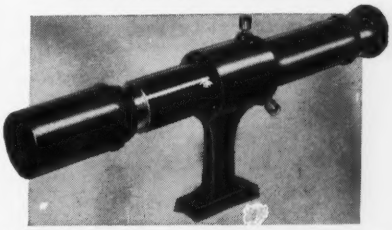
Stock #70,068-Y..............................$14.95 ppd.

"MAKE-YOUR-OWN" 4¼" MIRROR KIT

The same fine mirror as used in our telescopes, polished and aluminized, lenses for eyepieces, and diagonal. No metal parts.

Stock #50,074-Y..............................$16.25 ppd.

6X FINDER TELESCOPE



Has crosshairs for exact locating. You focus by sliding objective mount in and out. Base fits any diameter tube — an important advantage. Has 3 centering screws for aligning with main telescope. 20-mm. diam. objective. Weighs less than ½ pound.

Stock #50,121-Y..............................$8.00 ppd.

MISCELLANEOUS ITEMS

KELLNER EYEPIECE — 2" focal length (1¼" O.D.). Mount of black anodized aluminum.

Stock #30,189-Y........................$6.00 ppd.

60° SPECTROMETER PRISM — Polished surfaces 18-mm. x 30-mm. — flat to ½ wave length.

Stock #30,143-Y........................$8.25 ppd.

ASTRONOMICAL TELESCOPE TUBING

Stock No.	I.D.	O.D.	Lgth.	Description	Price
80,038-Y	**4⅞"**	**5¼"**	**46"**	**Spiral-wound**	**$2.50**
85,008-Y	**6⅞"**	**7⅜"**	**60"**	**paper**	**4.00**
85,011-Y	**2⅞"**	**3"**	**48"**		**6.00**
85,012-Y	**3⅞"**	**4"**	**60"**		**8.75**
85,013-Y	**4⅞"**	**5"**	**48"**	**Aluminum**	**9.00**
85,014-Y	**6⅞"**	**7"**	**60"**		**15.00**

All tubing is shipped f.o.b. Barrington, N. J.

BE SURE TO GET FREE CATALOG "Y"

Fantastic variety — never before have so many lenses, prisms, optical instruments, and components been offered from one source. Positively the greatest assembly of bargains in all America. Imported! War Surplus! Hundreds of other hard-to-get optical items. Write for Free Catalog "Y."

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CELESTIAL CALENDAR

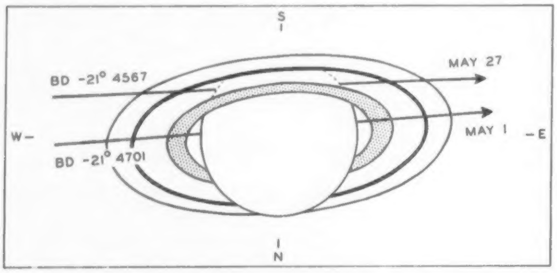
Universal time is used unless otherwise noted.

OCCULTATIONS BY SATURN

Saturn will pass in front of two faint stars in Ophiuchus during May. On the morning of May 1st the planet will occult the 8.8-magnitude star BD −21° 4701. Both the opening and final stages may be seen from the South Pacific, but only the disappearance of the star behind the outer ring will be visible from the western United States. This is predicted for 10:49 Universal time, as seen from Palomar Observatory in California, according to the 1958 *Handbook* of the British Astronomical Association. The diagram shows the apparent path of the star relative to Saturn.

The same diagram also indicates the occultation by Saturn of the 9.0-magnitude star BD −21° 4657 during the early morning of May 27th. The event will be generally visible from North America. At Montreal, the star goes behind the outer edge of the ring at 7:09 UT, and behind the western limb of the planet at 8:00, emerging from the eastern limb at 9:18. Morning twilight will prevent watching the emergence of the star from the ring. At Palomar, the corresponding times will be 7:14, 8:03, and 9:20, respectively, with the final reappearance of the star from the ring at 10:23 UT.

Large apertures and good seeing will be needed for satisfying views of these rather difficult phenomena. *Sky and Telescope* will welcome observational reports, including accurate timings of the contacts.



A schematic view of the occultation of two faint stars by Saturn this month. The crepe ring is shaded, and Cassini's division is the heavy line between the outer ring A and ring B.

MAY METEORS

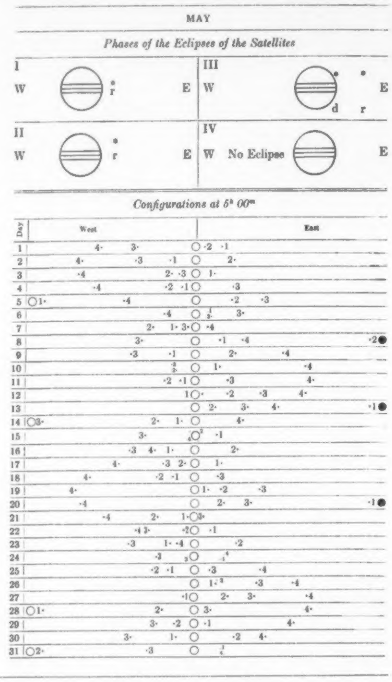
The moon, just past full, will seriously interfere with observations of the Eta Aquarid meteor shower this month. Maximum will occur on the morning of May 5th; under good sky conditions up to 12 meteors per hour might be counted by a single observer. On the date of maximum, the radiant will be at right ascension 22^h 24^m, declination 0°, and it will shift northeastward by one degree each day.

W. H. G.

JUPITER'S SATELLITES

The configurations of Jupiter's four bright moons are shown below, as seen in an astronomical or inverting telescope, with north at the bottom and east at the right. In the upper part, *d* is the point of disappearance of the satellite in Jupiter's shadow; *r* is the point of reappearance.

In the lower section, the moons have the positions shown for the Universal time given. The motion of each satellite is from the dot toward the number designating it. Transits over Jupiter's disk are shown by open circles at the left, eclipses and occultations by black disks at the right. The chart is from the *American Ephemeris and Nautical Almanac.*



MINIMA OF ALGOL

May 2, 1:42; 4, 22:31; 7, 19:20; 10, 16:09; 13, 12:58; 16, 9:47; 19, 6:36; 22, 3:24; 25, 0:13; 27, 21:02; 30, 17:51. June 2, 14:40; 5, 11:29; 8, 8:18.

These minima predictions for Algol are based on the formula in the 1953 *International Supplement* of the Krakow Observatory. The times given are geocentric; they can be compared directly with observed times of least brightness.

OCCULTATION PREDICTIONS

May 8-9 **Beta Capricorni** 3.2, 20:18.7 −14-54.9, 20. Im: **A** 7:00.8 −1.4 +2.3 43; **B** 7:06.4 −1.3 +2.4 36; **C** 6:46.7 −1.3 +2.2 51; **D** 6:54.8 −1.2 +2.4 41. Em: **A** 8:07.4 −1.9 +0.3 290; **B** 8:06.5 −1.8 +0.3 297; **C** 7:57.4 −1.8 +0.6 284; **D** 7:56.2 −1.5 +0.5 294; **E** 7:38.9 −1.0 +0.9 285; **F** 7:22.4 −0.9 +1.3 261.

May 30-31 **Alpha Librae** 2.9, 14:48.6 −15-52.1, 12. Em: **A** 0:32.4 −2.1 +2.5 236; **B** 0:36.8 −1.7 +1.9 245.

For stations in the United States and Canada, usually for stars of magnitude 5.0 or brighter, data from the *American Ephemeris* and the *British Nautical Almanac* are given here, as follows: evening-morning date, star name, magnitude, right ascension in hours and minutes, declination in degrees and minutes, moon's age in days, immersion or emersion; standard-station designation, UT, **a** and **b** quantities in minutes, position angle on the moon's limb; the same data for each standard station westward.

The **a** and **b** quantities tabulated in each case are variations of standard-station predicted times per degree of longitude and of latitude, respectively, enabling computation of fairly accurate times for one's local station (long. **Lo,** lat. **L**) within 200 or 300 miles of a standard station (long. **LoS,** lat. **LS**). Multiply **a** by the difference in longitude (**Lo − LoS**), and multiply **b** by the difference in latitude (**L − LS**), with due regard to arithmetic signs, and add both results to (or subtract from, as the case may be) the standard-station predicted time to obtain time at the local station. Then convert the Universal time to your standard time.

Longitudes and latitudes of standard stations are:

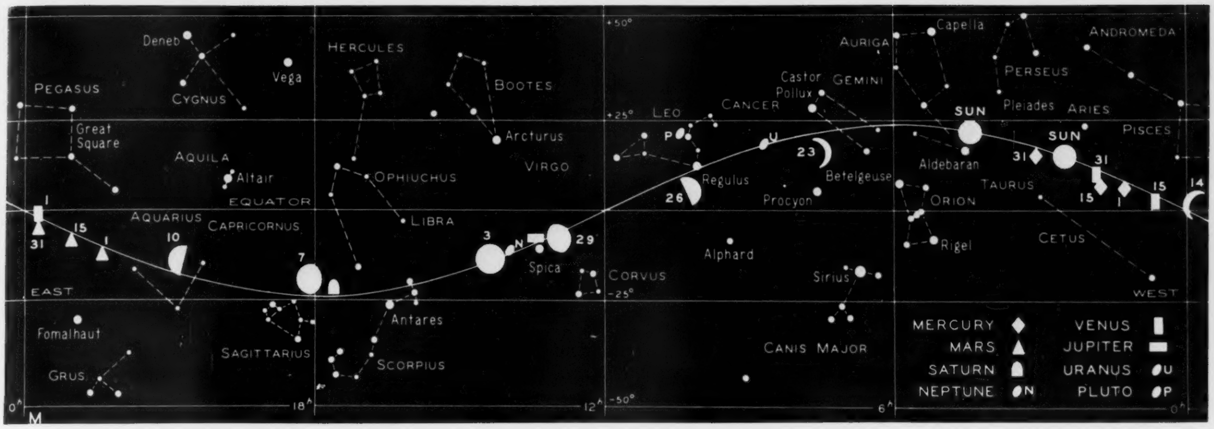
A	+72°.5,	+42°.5	**E**	+91°.0,	+40°.0
B	+73°.6,	+45°.5	**F**	+98°.0,	+31°.0
C	+77°.1,	+38°.9	**G**	Discontinued	
D	+79°.4,	+43°.7	**H**	+120°.0,	+36°.0
			I	+123°.1,	+49°.5

VARIABLE STAR MAXIMA

May 1, S Hydrae, 084803, 7.9; 9, R Aurigae, 050953, 7.8; 9, RV Sagittarii, 182133, 7.8; 11, S Pegasi, 231508, 8.0; 11, X Centauri, 114441, 7.8; 16, R Cassiopeiae, 235350, 6.5; 28, R Sagittarii, 191019, 7.2; 28, S Coronae Borealis, 151731, 7.5; 29, RU Sagittarii, 195142, 7.2.

June 2, R Canum Venaticorum, 134440, 7.7; 6, R Caeli, 043738, 8.0; 7, RS Herculis, 171723, 8.0; 7, T Centauri, 133633, 6.1.

These predictions of variable star maxima are by the AAVSO. Only stars are included whose mean maximum magnitudes are brighter than magnitude 8.0. Some, but not all of them, are nearly as bright as maximum two or three weeks before and after the dates for maximum. The data given include, in order, the day of the month near which the maximum should occur, the star name, the star designation number, which gives the rough right ascension (first four figures) and declination (bold face if southern), and the predicted magnitude.



THE SUN, MOON, AND PLANETS THIS MONTH

The sun, on the ecliptic, is shown for the beginning and end of the month. The moon's symbols give its phase roughly, with the date marked alongside. Each planet is located for the middle of the month or for other dates shown. All positions are for 0^h Universal time on the respective dates.

The moon is to be partially eclipsed on May 3rd, for observers in western North America, the Pacific Ocean area, eastern Asia, and Australia. At maximum, only 1.5 per cent of the moon's diameter will be obscured by the umbra of the earth's shadow. The penumbral eclipse will begin at 10:10 UT, with first umbral contact at 12:00 and mid-eclipse at 12:13. The moon will leave the umbra at 12:26, and the penumbra at 14:16.

Mercury reaches greatest western elongation on the 14th, 26° from the sun. Rising about an hour before the sun, Mercury will then be at magnitude +0.7 but poorly placed for observation, low in the southeastern sky.

Venus is a morning star in May, rising about two hours before the sun on the 15th and of magnitude −3.6. In a telescope, its gibbous phase may be seen; its disk is 66-per-cent illuminated and 17″.4 in diameter.

Mars is in the morning sky in Aquarius, rising in midmonth about three hours before the sun. The red planet is of magnitude +0.8, with a telescopic disk only 7″ across.

Jupiter crosses the meridian about 10 p.m., local time, in the middle of the month, and can be seen until dawn. The planet is of magnitude −2.0, situated in eastern Virgo. Its telescopic appearance is striking, the flattened disk having an equatorial diameter of 43″ and a polar diameter of 40″. The moon will pass near Jupiter during the night of May 1-2, conjunction occurring on the 2nd at 9:21 UT, with the planet 2° 11′ north, as seen from the earth's center.

Saturn will rise about two hours after sunset on the 15th, and will be visible the rest of the night as a +0.4-magnitude object in Ophiuchus. Its telescopic disk is 16″ in polar diameter; the major axis of the ring system is 41″. The rings are well placed for observation this season, the northern face inclined 26°.5 to our line of sight. The moon will be close to Saturn on the morning of May 6th, conjunction occurring at 10:22 UT, with the moon passing 2° 49′ north as seen from the earth's center. Saturn occults two faint stars this month; details are given elsewhere in this Celestial Calendar.

Uranus is a 6th-magnitude object in Cancer, located about 36′ north of Delta Cancri on May 15th. It is visible with binoculars in the western sky in early evening.

Neptune is retrograding in eastern Virgo, about $1\frac{1}{2}$° southwest of Kappa Virginis in midmonth. This 8th-magnitude planet may be seen in a small telescope as a disk 2″.5 in diameter.

Artificial satellite observers should use the star chart in this issue for early evening observations; morning observers will find the chart from a September issue useful.

W. H. G.

UNIVERSAL TIME (UT)

TIMES used in Celestial Calendar are Greenwich civil or Universal time, unless otherwise noted. This is 24-hour time, from midnight to midnight; times greater than 12:00 are p.m. Subtract the following hours to convert to standard times in the United States: EST, 5; CST, 6; MST, 7; PST, 8. If necessary, add 24 hours to the UT before subtracting, in which case the result is your standard time on the day preceding the Greenwich date shown.

MINOR PLANET PREDICTIONS

Eunomia, 15, 9.4. April 27, 16:02.6 −35-07. May 7, 15:54.1 −34-53; 17, 15:44.3 −34-23; 27, 15:34.1 −33-35. June 6, 15:24.8 −32-36; 16, 15:17.1 −31-29.

Lampetia, 393, 9.9. April 27, 16:03.0 −12-59. May 7, 15:57.7 −10-57; 17, 15:50.3 −8-50; 27, 15:42.2 −6-49. June 6, 15:34.7 −5-03; 16; 15:29.0 −3-42.

Hertha, 135, 9.9. May 7, 16:39.7 −26-05; 17, 16:31.7 −26-03; 27, 16:21.7 −25-49. June 6, 16:11.0 −25-26; 16, 16:01.3 −24-57; 26, 15:53.7 −24-27.

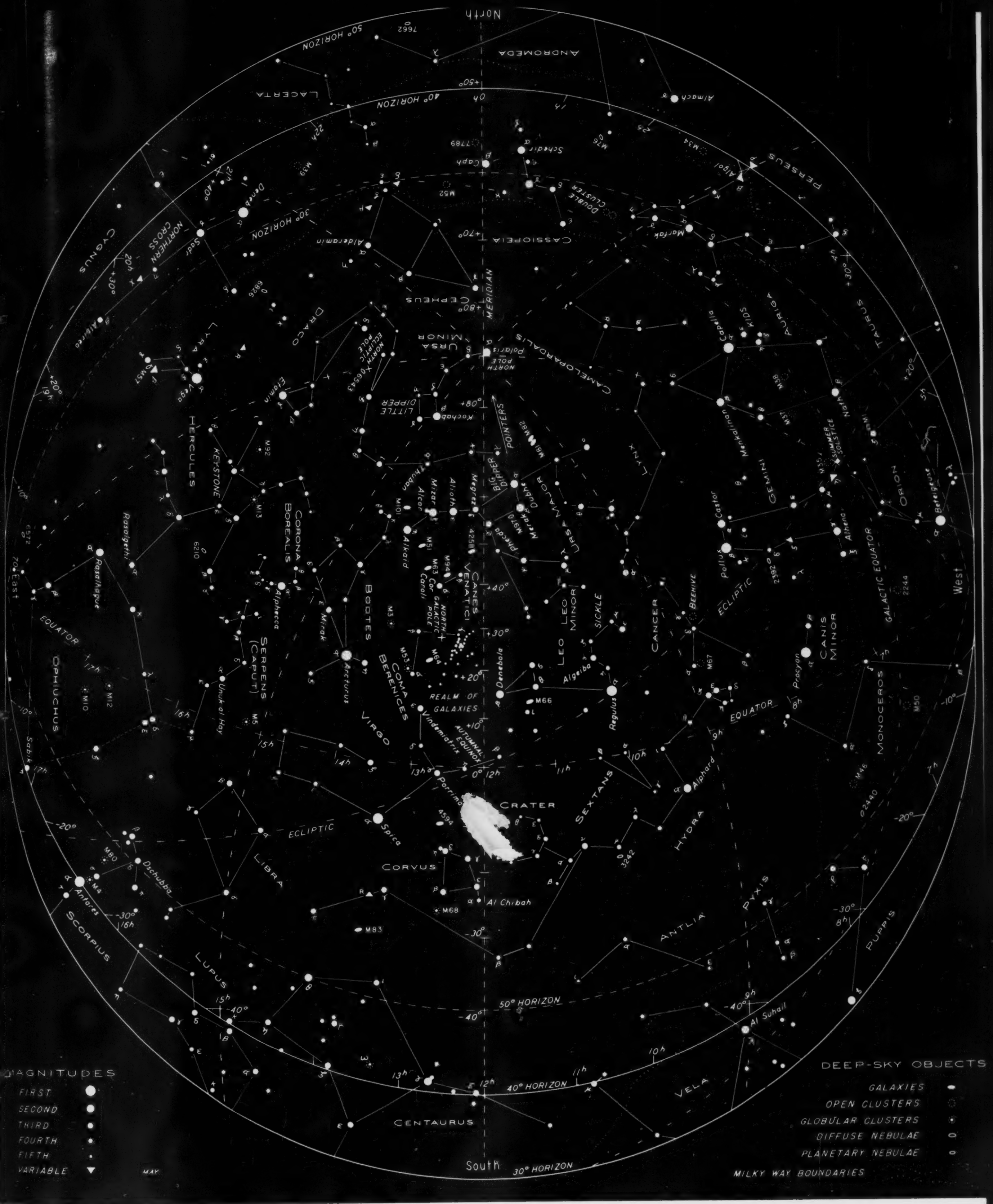
Ausonia, 63, 9.1. May 17, 17:28.8 −33-43; 27, 17:20.9 −34-00. June 6, 17:10.8 −33-59; 16, 16:59.9 −33-38; 26, 16:50.2 −33-02. July 6, 16:43.3 −32-16.

After the asteroid's name are its number and the magnitude expected at opposition. At 10-day intervals are given its right ascension and declination (1950.0) for 0^h Universal time. In each case the motion of the asteroid is retrograde. Data are supplied by the IAU Minor Planet Center at the University of Cincinnati Observatory.

MOON PHASES AND DISTANCE

Full moon	May 3, 12:23
Last quarter	May 10, 14:37
New moon	May 18, 19:00
First quarter	May 26, 4:38
Full moon	June 1, 20:55

	May	Distance	Diameter
Perigee	2, 6^h	223,400 mi.	33′ 14″
Apogee	14, 11^h	252,000 mi.	29′ 28″
Perigee	30, 7^h	226,300 mi.	32′ 49″
	June		
Apogee	11, 5^h	251,300 mi.	29′ 33″



STARS FOR MAY

The sky as seen from latitudes 30° to 50° north, at 9 p.m. and 8 p.m., local time, on the 7th and 23rd of May, respectively. For other dates, add or subtract ½ hour per week.

Ursa Major dominates the sky at the zenith these May evenings. The names of its seven Big Dipper stars are worth learning. Other bright stars near the meridian of this chart are Caph and Schedir in Cassiopeia, Polaris and Kochab in Ursa Minor, Cor Caroli in Canes Venatici, and Denebola in Leo.

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Lafayette's 160x, 62-mm. *Polaris*

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- 62-mm. Objective
- Micromotion adjustments on both axes
- Coated optics throughout
- Equatorial mount

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Finder scope is 6x, 30 mm. Equatorial mount with slow-motion controls in right ascension and declination. Tripod head with latitude adjustment. Clamp lever for declination and inclination. Accessories include sunglass, star diagonal, erecting prism, sun projection screen, field tripod, and wooden case. Magnifications of 160x, 88x, and 40x. Rack-and-pinion focusing. Heavy plating used throughout to prevent rusting. Shipping wt. 30 lbs.

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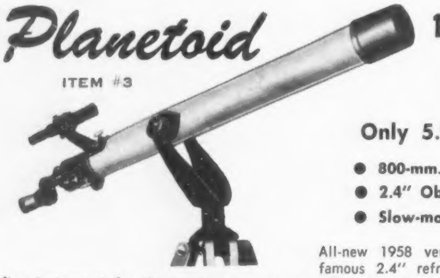
ITEM #2

Planetoid

ITEM #3



132x, 2.4"

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- 84x, 38x
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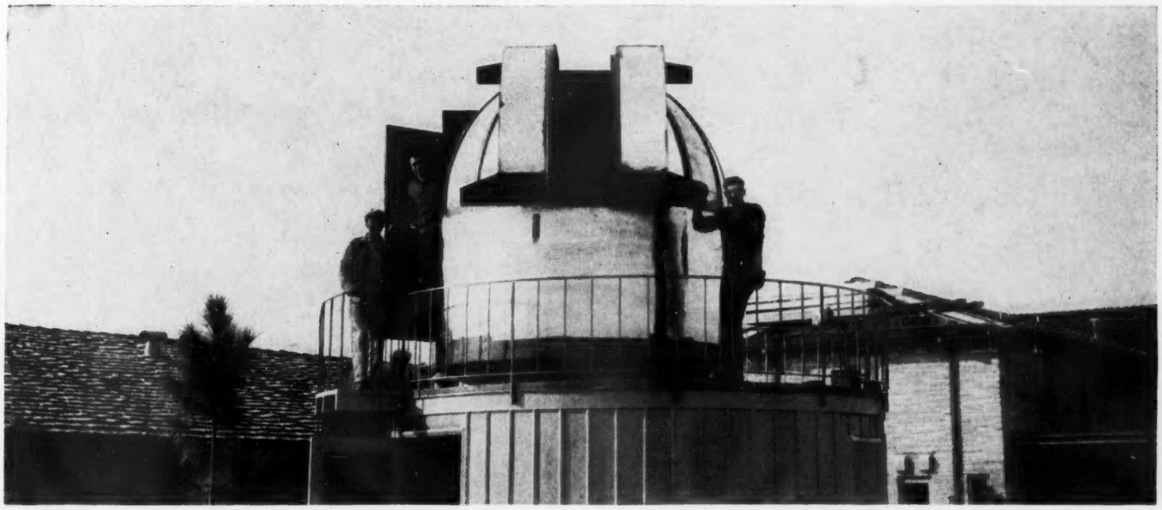

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